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The Ohio River Pollution Survey's Relation to Stream Pollution Problems in West Virginia

By E. S. Tisdale

THE State of West Virginia, the Health Department and the superintendents of water and sewage purification plants throughout the state, are being brought into closer working relationships with the U. S. Public Health Service than ever before through the present study of stream pollution in the Ohio River Basin.

This is perhaps the most comprehensive study of stream pollution ever undertaken in a large industrialized, economically important drainage basin. It is bringing about certain desirable working relationships between several different federal agencies concerned with water uses. It is demonstrating how federal and state public health services can be coordinated for the purpose of stream sanitation improvement. In addition, it is emphasizing one fundamental principle enunciated by the Water Resources Committee of the National Resources Committee, which perhaps has not been recognized and applied in the past, namely, the necessity for planning for the wisest use of the waters of a drainage basin considering all viewpoints, not alone for the protection of public health, but also for the preservation of aquatic and wild life, for recreational use, and as an aid to navigation, agriculture and industry.

A paper presented on October 13, 1939, at the West Virginia Section Meeting at Morgantown, W. Va., by E. S. Tisdale, Sanitary Engineer, Ohio River Pollution Survey, U. S. Public Health Service, Cincinnati.

Public Opinion Aroused on Stream Pollution Control

Before outlining the details of the present Ohio River Pollution Survey, it may be of interest to note certain recent events of unprecedented importance with respect to stream pollution control from a national standpoint.

For the first time in the history of this country, the President of the United States sent a message to Congress, suggesting ways and means to cope with the involved and perplexing questions of stream sanitation. On February 16, 1939, he transmitted to the House this report of the Special Advisory Committee on Water Pollution entitled "Water Pollution in the United States." Among other things President Roosevelt said, ". . . Unprecedented advances in cleaning up our streams have been made possible by the public works and work relief programs during the last six years. If this construction work is to continue at a substantial rate and if the necessary research, education and enforcement activities are to be carried out most effectively, the Federal Government must lend financial support and technical stimulation. The time is overdue for the Federal Government to take vigorous leadership along these lines."

The widespread public interest over the country in matters relating to stream sanitation is also reflected in the action which was taken by Congress in authorizing the study of an entire river basin, the Ohio, through a provision of the Rivers and Harbors Act approved in August, 1937. An agreement was reached for the joint activity of the Corps of Engineers of the U. S. Army, and the U. S. Public Health Service in carrying forward this three-year practical program on stream pollution in the Ohio River Basin. In the above mentioned Act, specific instructions were given "to ascertain what pollutive substances are being deposited directly or indirectly into the Ohio River, the sources and extent of such deposits with a view to determining *the most feasible method of correcting and eliminating the pollution of these streams.*" Likewise, the Water Resources Committee, in the publications of the National Resources Committee, has pointed to the Ohio River Basin as an outstanding one with most complex and varied stream pollution problems. The survey should serve as an example of the way in which federal and state water use and control agencies can work together to ascertain and solve problems of stream pollution control.

It may be possible to standardize stream pollution studies and set up a pattern for effectively carrying out a remedial program as a result of the Ohio River Pollution Survey.

Previous Drainage Basin Studies by U. S. P. H. S.

It is true that the U. S. Public Health Service has previously studied the main Ohio River, in 1914 and 1915 and again in 1929 and 1930. However, these studies were of a research nature and only about 30 per cent of the main Ohio and none of the tributaries were studied. This survey has as its aim the practical application of these principles of stream sanitation which have been worked out to a considerable extent through the previous research study.

There are three specific stream pollution investigations which were made by the Service, either at the request of the states or the Congress.

(1) The Upper Mississippi River Basin, particularly the sections near metropolitan areas at Minneapolis and St. Paul, was studied in 1926.

(2) The Potomac River Basin, with special reference to the conditions in the tidal section at and below Washington, D. C., was reported on during 1932.

(3) The coastal areas in and about Norfolk, Virginia, were subject to special investigation during 1934.

In these three cases, the studies were of a practical nature and definite remedial measures were outlined. In two of the three cases, partly as a result of the studies, modern sewage treatment plants have been constructed and are operating successfully.

The need for careful scientific study of drainage basins becomes apparent when it is realized that only three of the twenty river basins which form the Ohio Basin have been studied. The National Resources Committee, in its published report entitled "Drainage Basin Problems and Programs," recommended that detailed studies were advisable on 67 large drainage basins over the country.

Methods for Obtaining Sources of Pollution

The Office of Stream Sanitation, which is directing the Ohio River Pollution Survey, early in 1939 worked out cooperative arrangements with the state health departments of Ohio, West Virginia, Kentucky and Tennessee, as well as the Tennessee Valley Authority. Under the arrangements one or more assistant public health engineers were

stationed at the various department headquarters. Thus the field work of ascertaining the sources of stream pollution in West Virginia is being carried on in cooperation with the Sanitary Engineering Division of the West Virginia State Health Department. Two men have been assigned to work in each state.

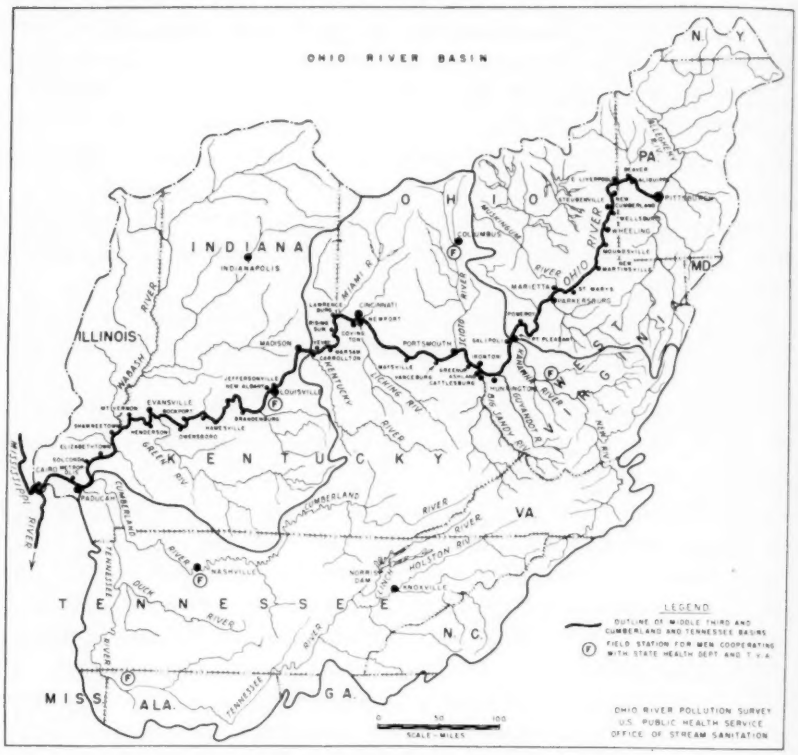


FIG. 1. Ohio River Basin Map, showing the Middle Third and the Tennessee and Cumberland Basins outlined with a heavy line

One of the assistant public health engineers, with headquarters at Charleston, has been working on detailed investigations of public water supplies, sewerage systems and sewage disposal practices in the cities and towns along the streams in southern West Virginia. An assistant chemical engineer is at work, investigating industrial wastes disposal in the Kanawha, Guyandot and Big Sandy Basins. These three drainage basins lie in the middle third of the Ohio Basin, which is being studied during 1939 (see Fig. 1).

The water supply and sewerage investigations in the Great Kanawha Basin are 70 per cent complete, in the Big Sandy 100 per cent complete, and in the Guyandot Basin about 25 per cent complete. Industrial waste studies on all three of these basins are also under way.

The cooperation of the State Health Department in making available to the field engineer the reports and analyses relating to stream sanitation in each community is extremely helpful. The field engineer goes into the territory to acquaint himself with current conditions and to get additional information which will enable the central office at Cincinnati to calculate the pollution load on the stream, and outline definite remedial measures.

The eight field engineers at work in the four states, on September 30, 1939, had completed 673 investigations on public water supplies, 673 studies on sewage disposal and reported upon 309 industrial waste plants during the first nine months of work.

In Tennessee the cooperative work with the Tennessee Valley Authority and Tennessee Health Department is going forward in a slightly different way, intensive industrial waste studies being under way in the Cumberland and Tennessee River Basins.

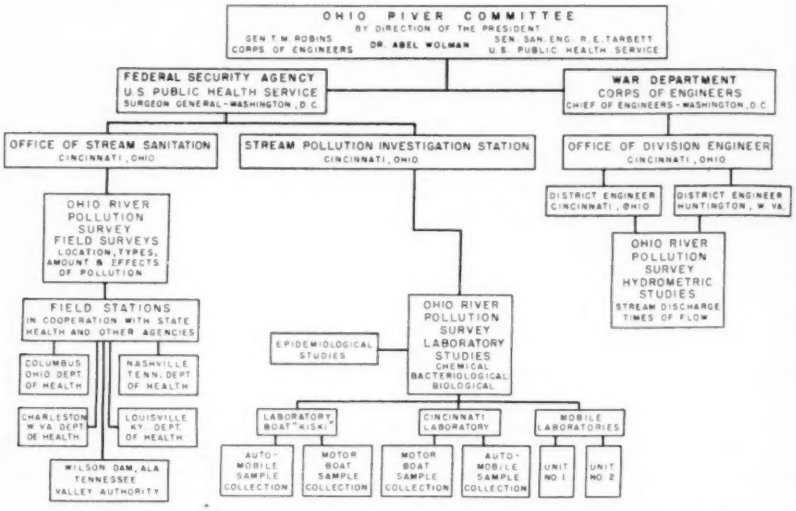
Stream Surveys by Several Laboratory Units

Ingenious methods have been worked out by the engineers in charge of the laboratory side of the survey program.

Whereas seventeen persons operate from the Stream Sanitation Station gathering factual data, 31 workers are associated with the laboratory studies, as indicated on the accompanying organization chart, Fig. 2. The first group of these 31 workers is located at the Stream Pollution Investigations Station at Cincinnati, Ohio. The second group is living and working on board the "Kiski," the floating laboratory at Ashland, Ky. This well equipped laboratory was formerly a quarterboat for the U. S. Army Engineers and the Corps of Engineers loaned the "Kiski" for the Ohio River Survey. A third laboratory group is working in the two auto-trailer laboratory units. These will travel over the tributaries, the upper portions of three drainage basins in Ohio and five river systems in West Virginia and Kentucky, which drain approximately 30,000 square miles of territory. Two sturdy 35-foot motorboats, formerly used by the Bureau of Fisheries, have been repaired and are used in the Ashland and Cincinnati pools in back of the navigation dams,

to do intensive sampling in these highly polluted sections of the river, which need detailed study. For the collection of samples on the lower ends of the tributaries, and at dams along the 280-mile stretch of the Ohio, automobiles, on a regular time-table system, operate from the Central Cincinnati and the "Kiski" laboratories.

Since the work started, approximately twenty thousand laboratory tests have been made on nearly twelve thousand samples of water. The trailer laboratories went into operation in September and, with this increase in laboratory facilities, the number of samples collected will increase considerably.


OHIO RIVER COMMITTEE
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DR. ABEL WOLMAN
SEN. SAN. ENG. R. E. TARBETT U.S. PUBLIC HEALTH SERVICE
FEDERAL SECURITY AGENCY
U.S. PUBLIC HEALTH SERVICE
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CINCINNATI, OHIO
STREAM POLLUTION INVESTIGATION STATION
CINCINNATI, OHIO
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CINCINNATI, OHIO
DISTRICT ENGINEER CINCINNATI, OHIO
DISTRICT ENGINEER HUNTINGTON, W. VA.
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LOCATION, TYPES, AMOUNT & EFFECTS OF POLLUTION
OHIO RIVER POLLUTION SURVEY HYDROMETRIC STUDIES
STREAM DISCHARGE TIMES OF FLOW
FIELD STATIONS
IN COOPERATION WITH STATE HEALTH AND OTHER AGENCIES
EPIDEMIOLOGICAL STUDIES
OHIO RIVER POLLUTION SURVEY LABORATORY STUDIES
CHEMICAL BACTERIOLOGICAL BIOLOGICAL
COLUMBUS OHIO DEPT. OF HEALTH
NASHVILLE TENN. DEPT. OF HEALTH
CHARLESTON W. VA. DEPT. OF HEALTH
LOUISVILLE KY. DEPT. OF HEALTH
WILSON DAM, ALA TENNESSEE VALLEY AUTHORITY
LABORATORY BOAT "KISKI"
CINCINNATI LABORATORY
MOBILE LABORATORIES
AUTO-MOBILE SAMPLE COLLECTION
MOTOR BOAT SAMPLE COLLECTION
MOTOR BOAT SAMPLE COLLECTION
AUTO-MOBILE SAMPLE COLLECTION
UNIT NO. 1
UNIT NO. 2

FIG. 2. Organization Chart of the Ohio River Pollution Survey

Two Zones of Pollution Indicated by Tests

Those in charge of the laboratory work, after careful consideration, agreed upon the following determinations: temperature, turbidity, pH, alkalinity, total and volatile suspended matter, 24-hour bacterial plate count at 37°C., coliform bacterial count, dissolved oxygen, and 5-day B.O.D. at 20°C., and nitrites when considered necessary. Total soap hardness is run on typical stream samples.

In addition to the chemical and bacteriological work, a biologist is collecting and examining water samples microscopically. These biological examinations for determining the types of organisms in

the water and the study of the mud deposits will serve to give a more complete knowledge of what is going on in the stream.

Those in charge of the laboratory program have been watching carefully the shifting of pollution zones as the flood conditions of February and March, 1939 were succeeded by low flow in the main river and tributaries during August and September, 1939.

The biochemical and bacteriological results to date indicate two zones of relatively high pollution, one in the Huntington, W. Va. and Portsmouth, Ohio section, the other about 60 miles downstream from Cincinnati.

The tributary observations thus far have shown a high degree of pollution in the lower section of the Great Miami, several bad zones in the Little Miami, and bad spots in certain sections of the Big Sandy, Guyandot and Licking Rivers.

Hydrometric Studies by Corps of Engineers

In undertaking comprehensive stream pollution studies like the present one, there are three essential types of information:

(1) Data relating to public water supplies, stream sanitation and sewage disposal, particularly the total amounts of sewage and industrial wastes in terms of population equivalents.

(2) Stream surveys consisting of chemical, biochemical, and bacteriological tests to ascertain water quality and determine the effects of the above mentioned pollution.

(3) Stream flows, particularly the low flows, when critical conditions are likely to occur.

The third important link in the chain of stream pollution analysis becomes available through the cooperation with the U. S. Army Engineers, Ohio River Division Office at Cincinnati. The organization chart (Fig. 1) shows the relation of the three cooperating groups to the Ohio River Board of Engineers, which was appointed by the President to direct the survey.

The Corps of Engineers through its extensive work on the Ohio River relating to navigation and flood control has excellent records of stream flow in the Ohio Basin. The corps has closely operating relationships with the U. S. Geological Survey which affords current stream flow information. In order to obtain more data on low water flows additional engineers from the Corps of Engineers are at work now.

Epidemiological Studies of Gastro-Enteritis

The Ohio River Board has authorized a special study seeking the cause and prevalence of gastro-enteritis in Ohio River Basin communities, particularly those along the main river. This study is now underway under the supervision of the Stream Pollution Investigations Station at Cincinnati. It is an attempt to correlate mortality rates from diarrhea and enteritis in cities of the Ohio Valley with various environmental factors, particularly those relating to water supply.

Many of the superintendents of water filtration plants will probably be interested in this study which is being approached from the epidemiological, the engineering and the clinical angles. It is hoped that it will throw some light on the outbreaks of intestinal disease which have been recurring at frequent intervals in Ohio Valley cities during the past decade.

During 1939, since the Ohio River Survey work has been under way in West Virginia, certain encouraging trends with reference to stream pollution in West Virginia are apparent.

According to the records submitted to the Cincinnati office by the field engineers, the modern sewage treatment plant recently placed in operation at Bluefield is giving excellent results, and has cleared up a serious stream pollution condition on the Bluestone River. At Beckley two sewage treatment plants are nearing completion. It is predicted that these plants will correct serious nuisance conditions in Piney Creek, a tributary of the New River. The well integrated cooperative effort between the State Health Department and the federal public works and relief agencies is definitely bettering municipal waste disposal practices. This is resulting in improved stream sanitation.

The industrial waste disposal situation gives evidence of being attacked in such a way that industry is willing to cooperate in finding out what wastes are detrimental, how they affect the stream, and what should be done to reduce the load of pollution when it is too great.

The reports, on file in the office of the State Health Department and with the Water Commission, of stream surveys, of industrial wastes disposal and their effect upon the stream, of remedial works, in fact the record of improvements brought about through the practical work of sanitary and chemical engineers cooperating with

industries, such as tanneries, chemical plants, petroleum refineries, by-product coke plants, viscose plants, are such that this present survey can progress much more rapidly than was expected.

This present more detailed study of the drainage basins of West Virginia streams which discharge into the Ohio should give added impetus to the well grounded program now under way in West Virginia. It should show where the "sore spots" are, where oxygen depletion and consequent nuisances are likely to develop in the future, to what extent public water supplies are detrimentally affected by improper sewage disposal or industrial waste disposal practices, what influence acid mine drainage has on the streams of the state with reference to aquatic life, recreation and public water supplies, and what practical benefits have come from the abandoned mine-sealing program.

It is hoped that this survey will lay the foundation for stream sanitation planning of a practical nature, in the carrying out of which the federal, state and local water control agencies can work together harmoniously.

Summary

Considering the relationship of West Virginia stream pollution problems to the present Ohio River Survey, certain features seem to stand out prominently.

(1) Public opinion, in the formation of which the water works superintendents in West Virginia have played a definite part, is now demanding that our waterways be freed from obnoxious domestic and industrial wastes. The report to Congress, submitted by the President, attests the importance of stream pollution in the national life.

(2) The two assistant public health engineers of the U. S. Public Health Service, assigned to West Virginia to study and report upon sources of stream pollution from sewage and industrial wastes in southern West Virginia in 1939, are well along on their first year's program, due to the splendid records on file with, and made available by, the West Virginia State Health Department. In nine months' time, eight field engineers in four states have completed studies of 673 public water supplies, 673 sewage disposal systems and 305 industrial waste disposal investigations.

(3) The laboratory studies, being carried out on the quality of water in the streams, are progressing at a rapid rate. Approximately

20,000 tests have been completed in the central laboratory at Cincinnati, at the floating laboratory "Kiski" near Ashland, and in the auto-trailer laboratories on the tributaries. Definite zones of pollution on the main Ohio and on the tributaries are apparent from these laboratory tests.

(4) The U. S. Army Engineers are assembling stream flow data in the Ohio Basin, with particular reference to low flows in the Ohio and its tributaries. The entire Ohio River Survey is being carried on through an agreement between the Corps of Engineers, U. S. Army and the U. S. Public Health Service, each federal agency undertaking that portion of the work for which it was best qualified by available records, present facilities, previous experience and trained personnel.

(5) The records which have come into the Cincinnati office from West Virginia in the first nine months of the survey program indicate that good progress in that state is being made in coping with stream pollution problems. Several of the cities in the Great Kanawha River Basin are installing necessary sewage treatment works. The industries have a record of cooperating with the technical staff in order to reduce pollution from detrimental industrial wastes.

During 1940, the streams draining the Upper Ohio River Basin which comprises portions of New York state, Western Pennsylvania, Northern West Virginia and Eastern Ohio will be studied in detail. The floating laboratory "Kiski" will move from her present base at Ashland, Ky. to the Parkersburg, Wheeling and Pittsburgh sections of the main Ohio. The mobile trailer laboratory units will be utilized on the upper portions of the tributary streams in this Upper Basin.

The third year of the survey, 1941, will probably be devoted to a study of the lower portion of the Ohio to its mouth, together with the Indiana, Illinois and Tennessee territory draining into this lower section of the Ohio Basin.

West Virginia is cooperating wholeheartedly in the work of carrying forward the Ohio River Pollution Survey and definite benefits to the state should accrue on its completion.

Protection of Watershed for Syracuse Supply

By Arnold F. Gregory

DURING the years between 1821 and 1888, there was considerable agitation by the citizens of Syracuse for a pure and adequate water supply. After investigation by J. R. Croes, Skaneateles Lake was selected and its use as a source of water supply approved by the State Legislature. The City then bought the privately owned city distribution system and installed the necessary intake and conduits to establish the supply from Skaneateles Lake.

In inaugurating the new supply, it was necessary for the City to make numerous changes on the watershed, which has an area of 60.3 square miles, exclusive of the lake. During the years 1894 to 1898, this work consisted of relocating outhouses and constructing some septic tanks or cesspools. Outhouses which were found to be too close to brooks flowing into the lake were placed at a greater distance from these streams.

On February 28, 1896, the first rules of the State Department of Health for watershed control were enacted and later posted by the City at various locations on the watershed.

Inasmuch as Skaneateles is the only village of any size on the watershed, and is located at the north end of the lake, this was the only community where the installation of a sewer system was necessary. As the village also utilizes the lake as a water supply, a plan was worked out whereby the village and the city would share the cost of installing the sanitary sewer system, which was completed in 1904. During this same year, the City established a watershed patrol, consisting of one man who made inspections of farms, cottages, streams and the lake shore.

In 1906 the Mayor appointed a committee, selected from the staff of the Medical College and the Chamber of Commerce, to make

A paper presented on November 2, 1939, at the New York Section Meeting at Utica, N. Y., by Arnold F. Gregory, Assistant Engineer, Division of Water, Syracuse, N. Y.

periodic inspections and recommend improvements on the watershed. As a result, sewage disposal works consisting of septic tank installations were made by the City to serve existing hotels at Fair Haven and Glen Haven at the south end of the lake. These hotels were later purchased by the City and razed to eliminate conditions which were otherwise difficult to cope with.

By 1908 cottages had become so numerous along the lake shore that it was found advisable to establish a system of servicing outhouses, which would eliminate any danger of pollution from this source. To accomplish this the City required that outhouses be so constructed that pails could be used instead of pits. These pails were delivered to the cottages as needed, and collected by the City. They were then taken to the property of the City at Glen Haven, where the excreta was buried.

After the purchase of the Glen Haven property, the sanitary inspector was placed under Civil Service and quartered at this location. A check on the number of farms and cottages made by the inspector in 1914 showed 610 farms and 225 cottages at that time.

About 1917 the City purchased a chlorinator and began chlorination of the water taken from the lake. During 1922, a study of algae growths was also begun.

By 1925, it was found necessary to have two sanitary inspectors, and in 1929 the State Department of Health enacted new rules for the watershed. Under the rules, the watershed is divided into districts and zones. District *A* extends from the north end of the lake to a line between Mandana and Five Mile Point; District *B* from *A* to a line between New Hope and Ten Mile Point; and District *C* from *B* to the southerly end of the watershed (see Figs. 1 and 2). The zones in the various districts are measured from the lake shore or from any natural or artificial water course leading to the lake. Zone 1 is 50 ft. wide in District *A*, 30 ft. wide in *B* and 10 ft. in *C*. Zone 2 is 150 ft., 100 ft. and 50 ft., respectively in these districts. Zone 3 includes all other portions of the watershed. Restrictions were placed on sewage disposal methods in the various zones and districts.

After the enactment of the new rules, the engineering section of the Water Division became more active in supervising watershed control. In 1926, a sectional map of the watershed, on a scale of 400 ft. to the inch, was prepared to show sewage disposal methods of the cottages (Fig. 3). At the same time, the cottages were numbered,

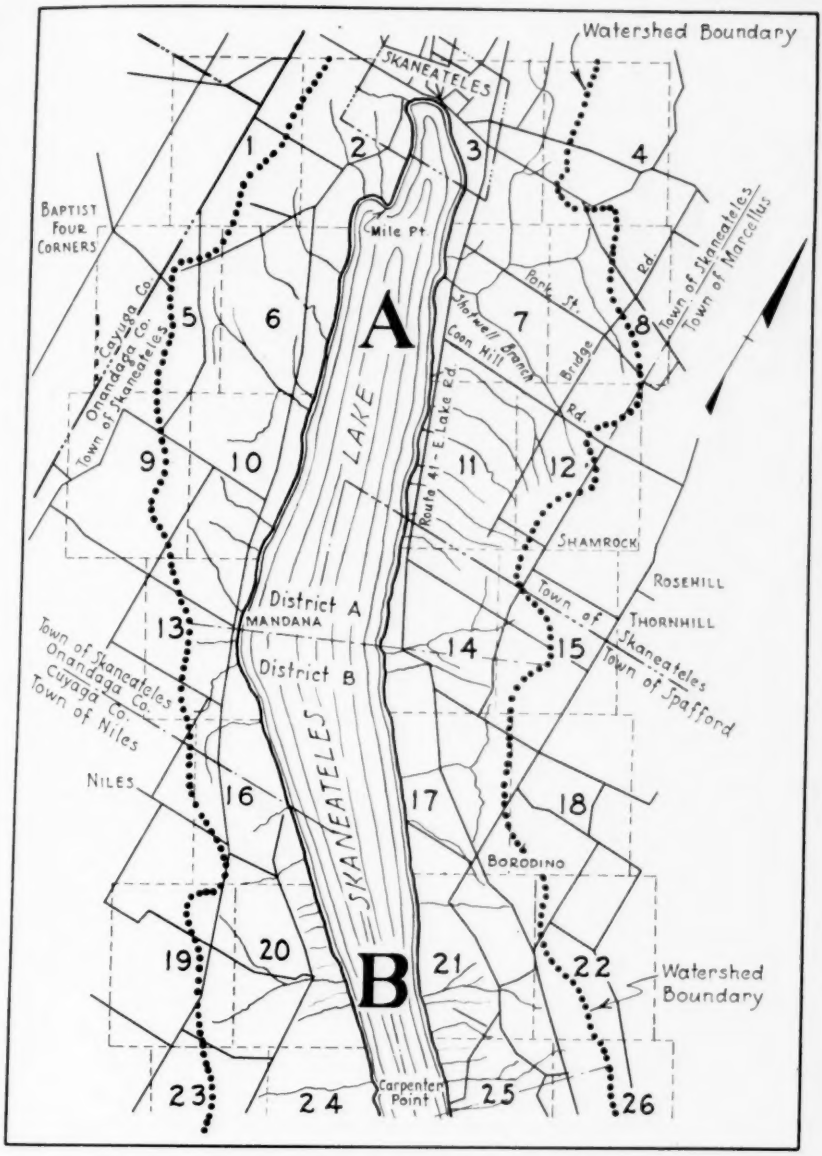


FIG. 1. Districts A and B of the Watershed Map as Divided into Districts and Divisions

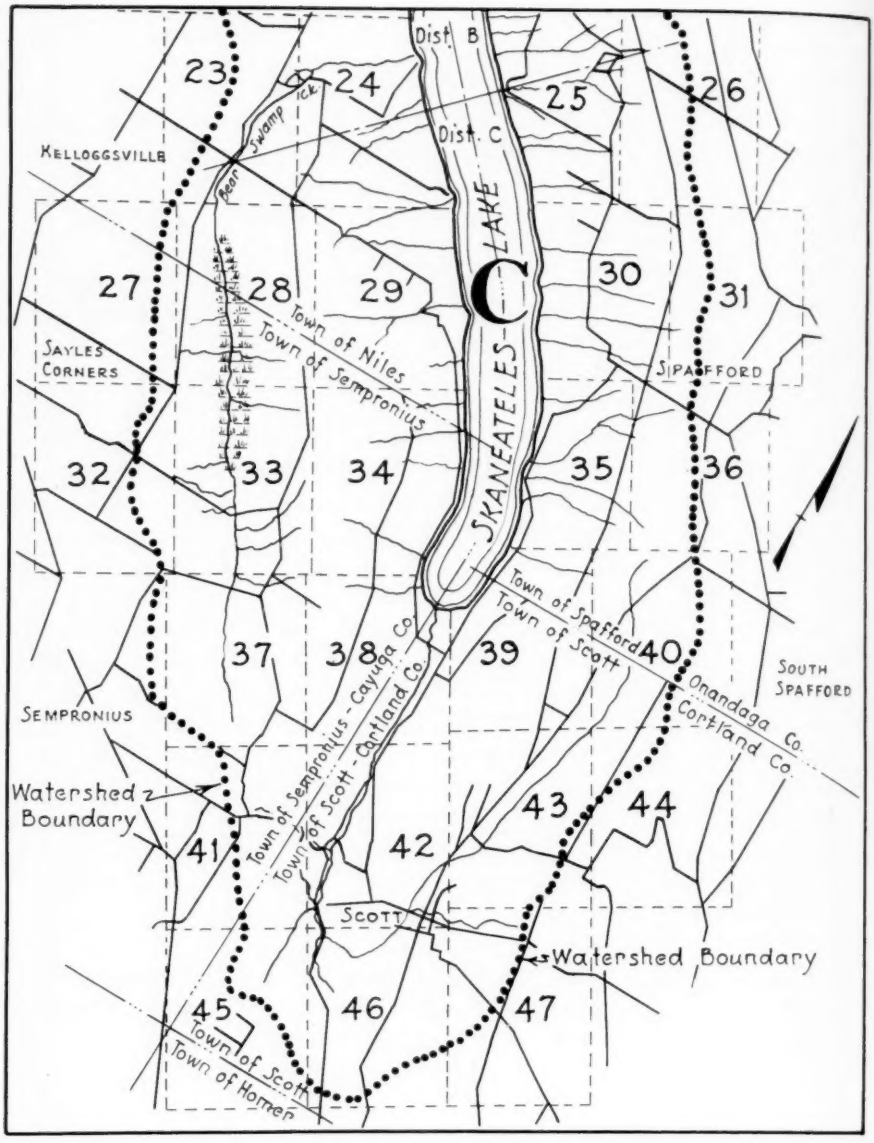


FIG. 2. District C of the Watershed Map

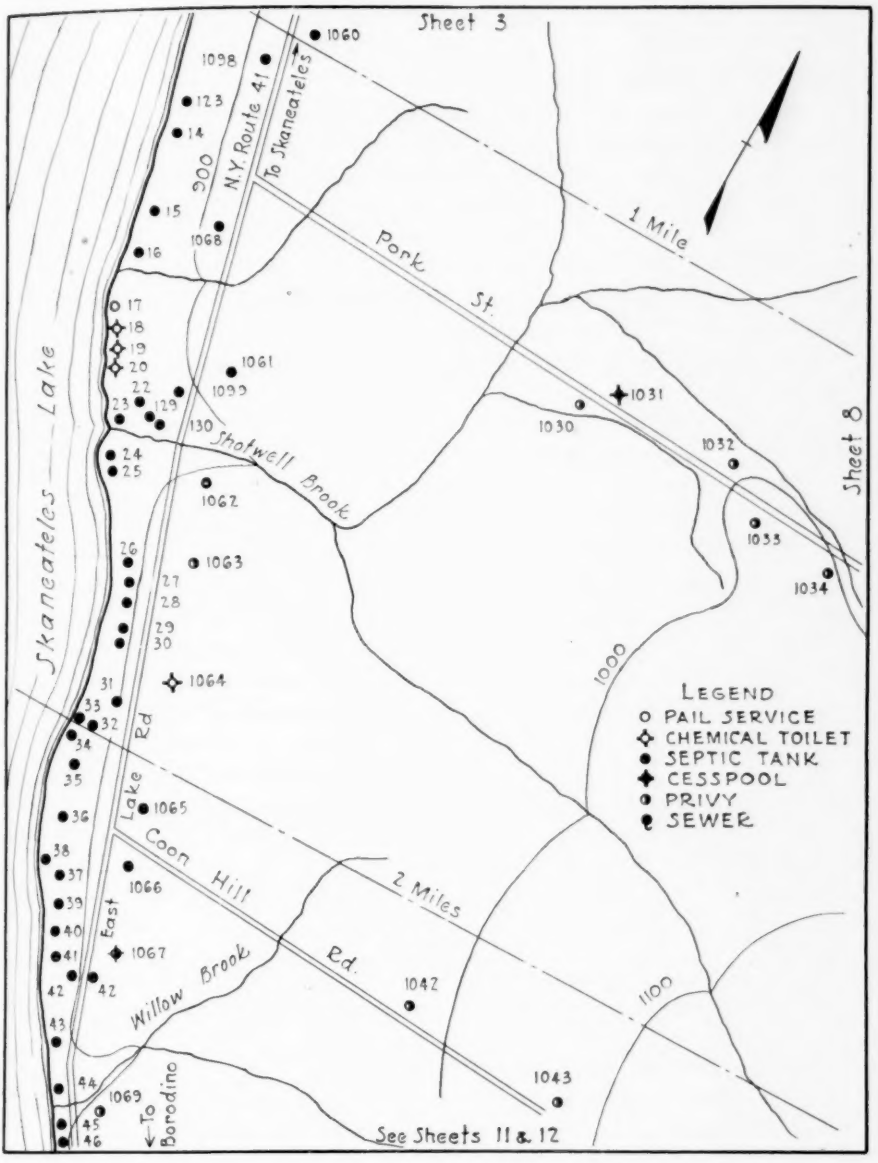
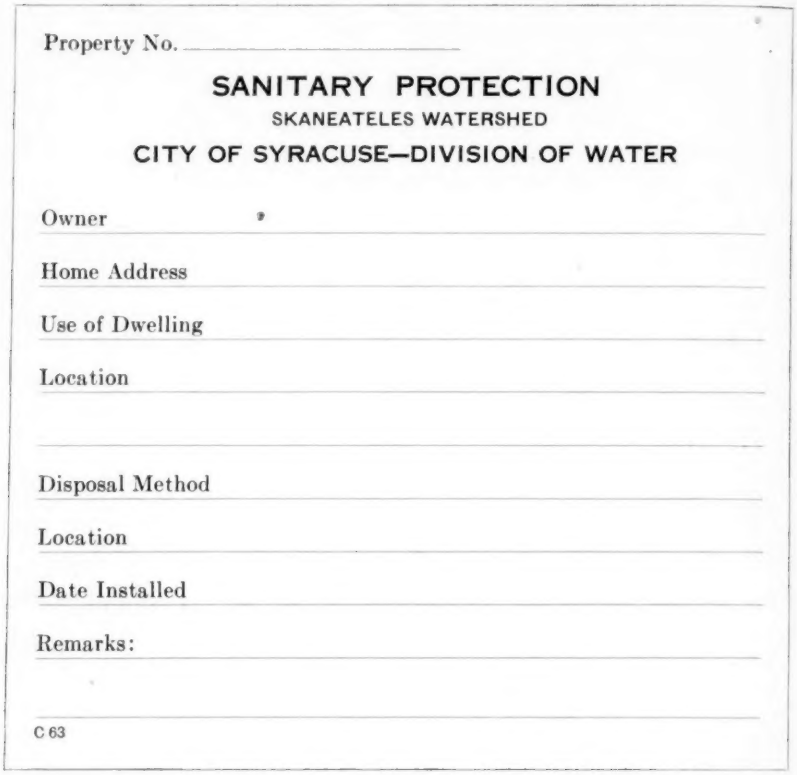


FIG. 3. Sample Sheet Showing Record of Sewage Disposal Methods

and a card file, including all pertinent information, established (Fig. 4). Treatment of the lake with copper sulfate to destroy algae growth was begun in 1927.

Several brooks which flowed through barnyards were found to be carrying barnyard wastes to the lake. To remedy these conditions, the City, during 1928, either diverted these streams or constructed


Property No. _____

SANITARY PROTECTION

SKANEATELES WATERSHED

CITY OF SYRACUSE—DIVISION OF WATER

Owner

Home Address

Use of Dwelling

Location

Disposal Method

Location

Date Installed

Remarks:

C 63

FIG. 4. Reduced Illustration of the 4 x 6 in. Card Used for Filing Information

culverts through the barnyards. In 1930, the City constructed storm water sewers in the village of Skaneateles to prevent street surface washings from entering the lake in that vicinity.

In 1929, there was instituted a further service for property owners on the watershed. This consists of taking applications for the installation of sewage disposal works, as required by the State Department of Health, making the necessary topographical survey and

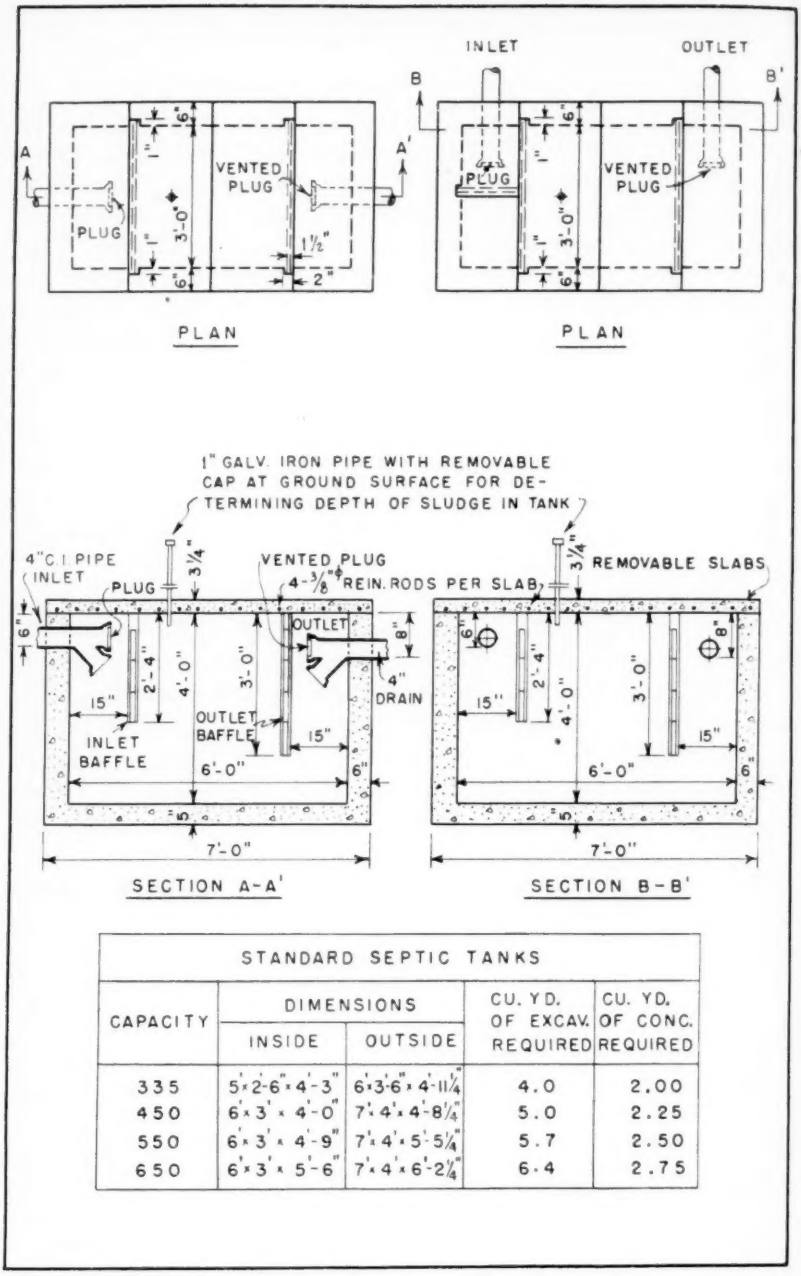
percolation tests, designing the system and preparing plans which are then submitted to the State for approval. After the issuance of the permit by the State, the City provides grade stakes and inspections to insure installation of the system in accordance with the plans. This service is provided at no expense to the property owners. Inasmuch as the terrain and soil conditions on the watershed vary considerably, it is necessary to utilize practically all methods for disposing of sewage effluent in the ground. To facilitate the choice of methods and the preparation of plans, a set of standards was developed and submitted to the State for approval. These include various acceptable types of septic tanks, leaching basins, typical leaching trench section and distributing basins (see Figs. 5 through 9). The distributing basin, which was designed by the City, has proven so successful in controlling the operation of these systems that it is now used on all disposal works involving more than one line of leaching tile trench.

In the past five years, the City has eliminated sink wastes from brooks in District *A*, and has constructed pits for manure storage in barnyards draining to the lake (Figs. 9 and 10). A complete survey of all the dwellings on the watershed was made, and a new watershed map prepared in 47 sections. All dwellings and cottages on the watershed have been numbered, and a complete card file established. These cards show both the method of sewage disposal and the proximity to any water course. At present there are 486 farms and 504 cottages on the watershed.

The sewage disposal methods in use at these dwellings are as follows:

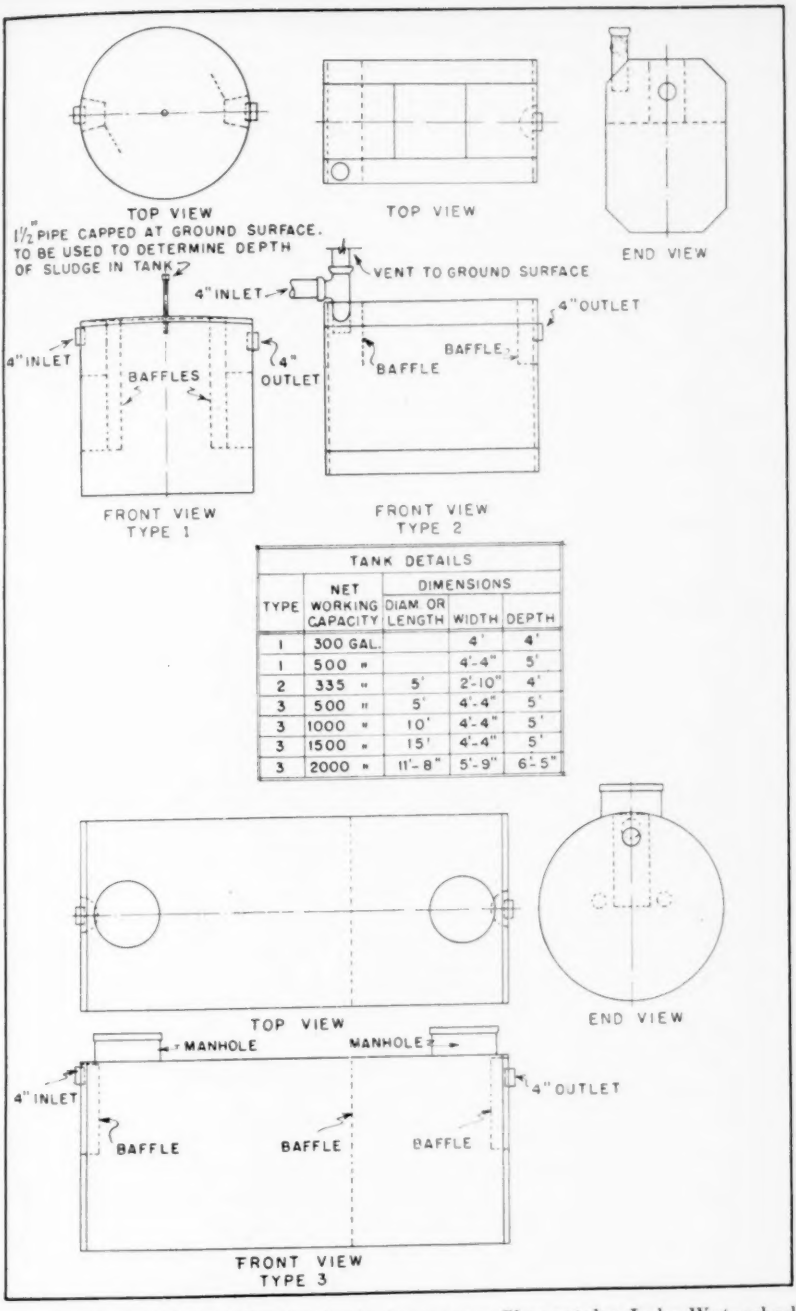
TYPE OF DISPOSAL	COTTAGES	FARMS	TOTAL
Septic Tank	186	114	300
Cesspool	4	24	28
Chemical Toilet	12	18	30
Pail Service	296	11	307
Pit Privy—dirt	6	305	311
Pit Privy—concrete	—	2	2
Pit Privy—w/container	—	12	12
Total	504	486	990

A large septic tank has been constructed for the disposal of excreta collected by the pail collection service, and the disposal by



STANDARD SEPTIC TANKS				
CAPACITY	DIMENSIONS		CU. YD. OF EXCAV. REQUIRED	CU. YD. OF CONC. REQUIRED
	INSIDE	OUTSIDE		
335	5'-2-6" × 4'-3"	6'-3'-6" × 4'-11¼"	4.0	2.00
450	6' × 3' × 4'-0"	7' × 4' × 4'-8¼"	5.0	2.25
550	6' × 3' × 4'-9"	7' × 4' × 5'-5¼"	5.7	2.50
650	6' × 3' × 5'-6"	7' × 4' × 6'-2¼"	6.4	2.75

FIG. 5. Standard Concrete Septic Tanks for use on Skaneateles Lake Watershed; designed by A. F. Gregory



TANK DETAILS

TYPE	NET WORKING CAPACITY	DIMENSIONS		
		DIAM. OR LENGTH	WIDTH	DEPTH
1	300 GAL.		4'	4'
1	500 "		4'-4"	5'
2	335 "	5'	2'-10"	4'
3	500 "	5'	4'-4"	5'
3	1000 "	10'	4'-4"	5'
3	1500 "	15'	4'-4"	5'
3	2000 "	11'-8"	5'-9"	6'-5"

FIG. 6. Typical Metal Septic Tanks for use on Skaneateles Lake Watershed

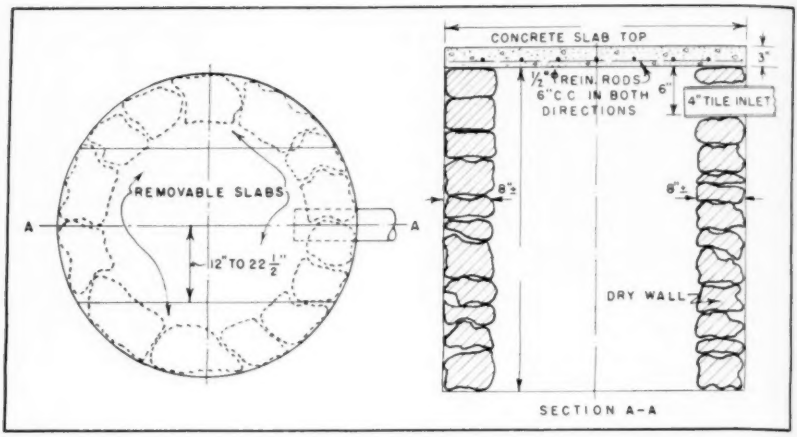


FIG. 7. Standard Leaching Basin for use on Skaneateles Lake Watershed; designed by A. F. Gregory

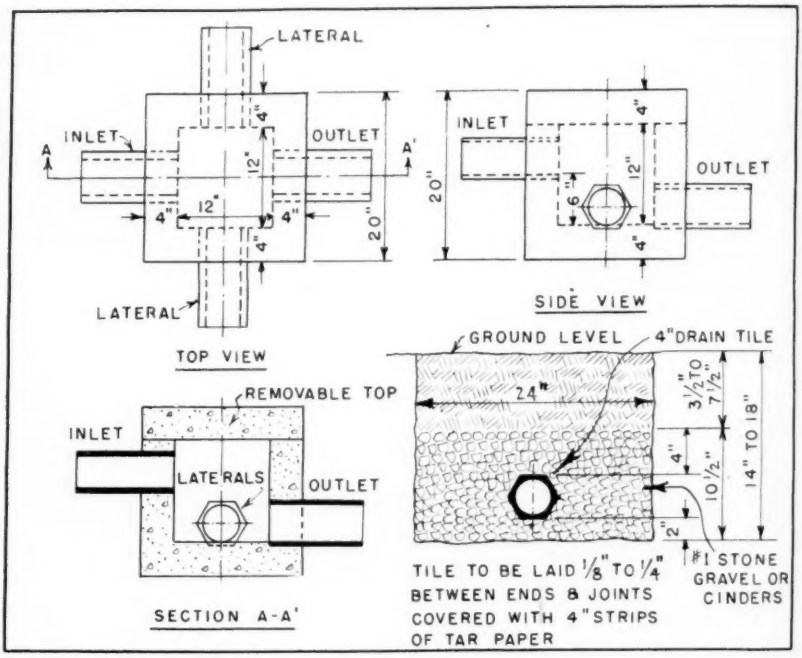


FIG. 8. Typical Section of Lateral Trench and Standard Distributing Basin for use in sewage disposal systems on Skaneateles Lake Watershed; designed by A. F. Gregory

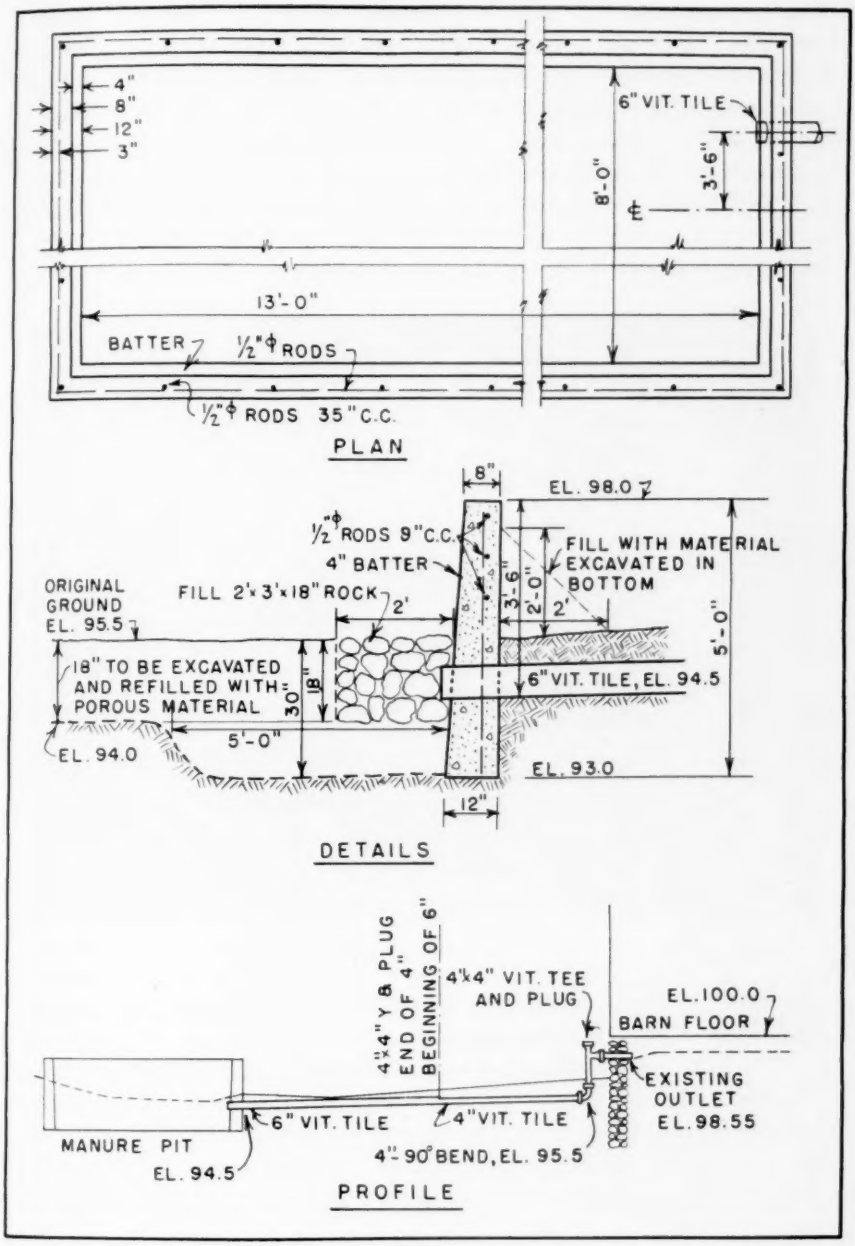


FIG. 9. Plan for a Manure Pit

burial discontinued. As it is necessary to use both boat and truck to collect these pails, a new truck of special design, which is entirely enclosed, has also been put in service. An automatic device for cleansing these pails has also been developed. After the installation of an additional intake in 1938, three chlorinators were installed to ensure continuous chlorination.

In 1938, the Division of Water of the City of Syracuse started to control the growth of algae in the waters of Skaneateles Lake by spraying a copper sulfate solution on the surface. Prior to this time,

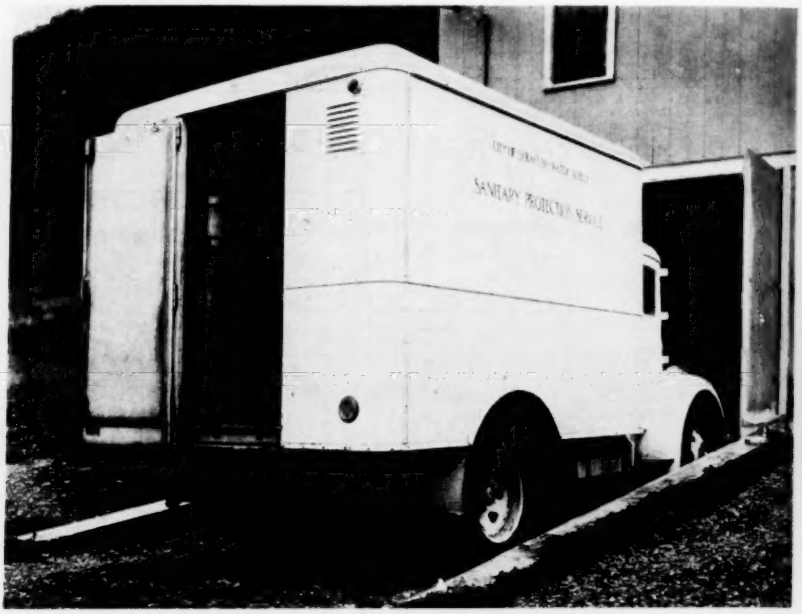


FIG. 10. The Pail Service Truck

the water had been treated by the old method of dragging the copper sulfate in burlap bags alongside a boat.

The new method was tried because the local Fish and Game Club claimed that the old method was killing fish due to the high copper sulfate concentration caused by poor distribution. Three treatments of eleven tons each have been successfully applied and the killing of fish eliminated. This is attributed to the fact that the dosage is more uniform.

The solution is laid down as a fine spray over a lane 30 to 40 ft.

wide (Fig. 11). These lanes run crosswise of the lake, parallel with the trough of the waves, and approximately 500 ft. apart. An 11-ton application takes 24 hours, which is more time than required by the old method. The copper sulfate is bought in crystal form, packed in paper bags ready for use; whereas previously it came in barrels and had to be placed in the burlap bags. The additional application time about equals the time it took to bag the crystals for the old method of application.

The crystal sizes must meet certain grading specifications. All crystals must pass a 3-mesh sieve, 50 per cent be retained on a 8-mesh and 40 per cent be retained on a 20-mesh sieve. By experi-

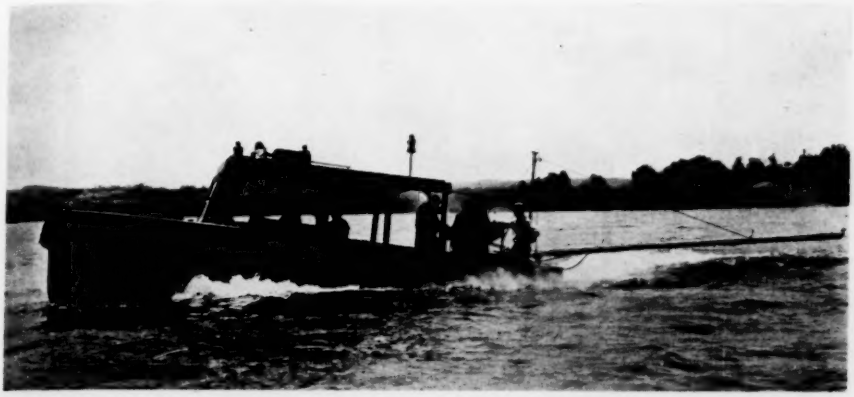


FIG. 11. Spraying the Copper Sulfate

ment, it was found that by keeping the size small the rate of dissolving was much faster, thereby lessening the application time.

The copper sulfate sprayer consists of a hopper with an adjustable regulating slide in the bottom (Fig. 12). Under this slide is a drum which is revolved by a small direct current motor connected to the storage battery of the boat. The speed of the motor is regulated by a rheostat. By cutting resistance in or out it is possible to change the r.p.m. of the motor and in this way control the rate of feed of the crystals.

Directly under the hopper and drum is located the dissolving tank. The crystals drop from the revolving drum into this tank and a small centrifugal pump discharges lake water on top of them. The depth of crystals in the tank is maintained at about 18 in. The lake water constantly dissolves the crystals and the copper sulfate solution is

pumped from the bottom of the tank by a gear pump and discharged through rubber hoses to nozzles mounted on the end of outriggers which extend from the stern of the boat. The two pumps are driven by a V-belt from a pulley which is mounted on the propeller shaft of the boat.

All of the spray equipment is portable and can be readily mounted in the stern of the boat, thus leaving plenty of empty space in the rest of the boat to place the bags of copper sulfate.

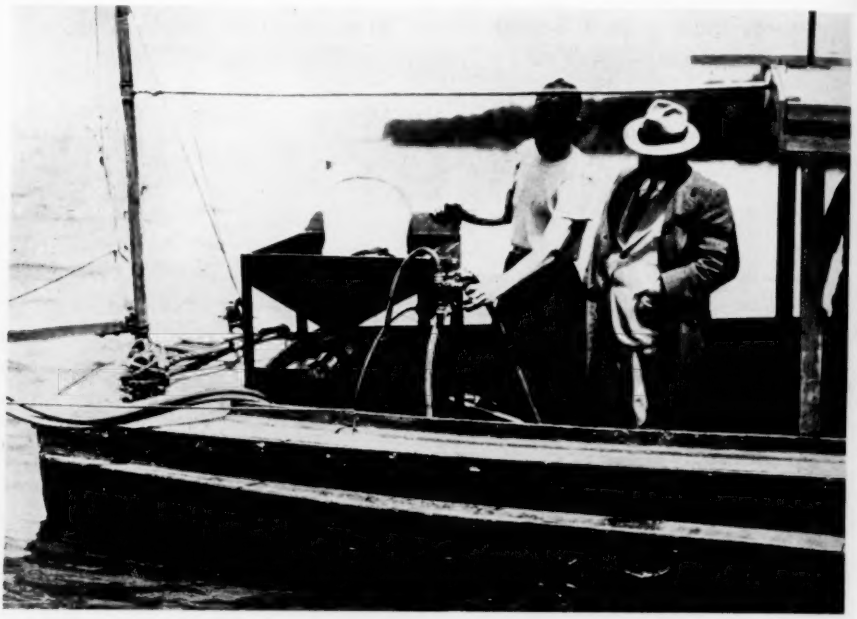


FIG. 12. The Portable Equipment in the Boat

Bacteriological tests and analyses of the water were made periodically for a number of years. During the past fifteen years, bacteriological tests have been made daily, and similar tests from brooks flowing into the lake made periodically, especially after heavy storms. Tests of well supplies of farms have also been made.

The inspectors make regular weekly reports, and immediately report to the engineers any violation. Where any outbreak from a septic tank is discovered, chloride of lime is immediately used by the inspector; and if necessary, the portable chlorinator owned by the City is put into operation.

The City and the Division of Water have made every effort during the past ten years to become familiar with all conditions existing on the watershed and to encourage property owners to eliminate those of an unsanitary nature. Wherever advisable and necessary, the City has assisted in this work. The property owners have been advised of the necessity of complete sanitation and efforts have been made to encourage them to cooperate for the protection of the health of their own families, inasmuch as they do not have the benefit of chlorination where they use the lake water in their cottages or homes. Where wells or springs are used as a source of water supply by the property owners, the greater danger of pollution has been called to their attention. This attitude of cooperation on the part of the City, rather than the attempt to resort to the force of law, together with continuous patrol by the inspectors, and the various services given gratus by the City, has resulted in practically complete co-operation by all property owners, so that we believe the city of Syracuse has one of the most carefully protected public watersheds in the country.

Possible Use of Ohio Conservancy Act for Developing and Operating Water and Sewerage Facilities In Metropolitan Areas

By F. H. Waring

As a result of the devastating flood of March, 1913, the Conservancy Act of Ohio was enacted February 17, 1914, for the specific purpose of providing for flood protection in the Miami Valley and any other area. Following the enactment of this Act the Miami Conservancy District was created, and flood detention dams and channel improvements were constructed throughout the Miami River Valley.

No particular reference was made in the original Conservancy Act to the development and operation of new water supply and sewage disposal facilities by a conservancy district, although it did contain some provisions for reconstructing existing water supply and sewerage works as might be necessary in the planning of a flood protection program.

Following the enactment of the Conservancy Act, there arose the specific problem of water supply for the metropolitan area involving Youngstown and Niles in the Mahoning Valley. In order to handle this problem upon a district basis there was enacted in June, 1919, the Sanitary District Act of Ohio. This Act was modelled closely along the lines of the Conservancy Act and purposed:

"To prevent and correct the pollution of streams, to provide for the collection and disposal of sewage and other liquid wastes, and for the development of district water supplies, to authorize the organization of sewerage and sanitation and water supply districts."

This Sanitary District Act is not to be confused with the County Sewer District Law of Ohio which was enacted many years previously to permit counties to extend and provide for water supply and sewer-

A paper presented on April 27, 1939, at the Ohio Section Meeting at Dayton, Ohio, by F. H. Waring, Chief Engineer, State Department of Health, Columbus, Ohio.

age facilities, usually in the vicinity of a city although not necessarily so. These county sewer districts are created by the county commissioners within a county and in them is vested the exclusive jurisdiction.

In both the Conservancy Act of Ohio and the Sanitary District Act of Ohio the district is created by, and the operation of the facilities is conducted under the jurisdiction of the courts of common pleas in the counties in which any portions of the conservancy district or sanitary district are situated. The idea of jurisdiction by the courts of common pleas, as set up in these Acts, is extremely popular as contrasted to the system whereby the sewer districts are in the hands of the county commissioners.

Some time previous to 1933, interests in the Muskingum Valley were concerned with the possibility of creating a conservancy district for flood protection. Preliminary reports on this matter were made by the Morgan Engineering Company. Thereafter, the Muskingum Conservancy District was organized and created in June, 1933. The work of the Muskingum Conservancy District has been confined to the development of flood retardation dams, reservoirs and channel improvements for the primary purpose of protecting the Muskingum Valley against damage by floods. Upon the advent of the P.W.A., advantage was taken of enlisting the aid of the Federal Government in financing and constructing these structures. This work is now practically completed.

In the operation of activities of the Miami Conservancy District and the Muskingum Conservancy District, it was observed that the original Conservancy Act of Ohio omitted some important features needed for the smooth conduct of construction and operation of flood protection facilities. It was also observed in the operation of the Sanitary District Act of Ohio that certain deficiencies existed. Some amendments to these two Acts were made relatively soon after the Miami and Mohoning districts began construction. To provide for a better method of amending the Conservancy Act, a committee was appointed under the administration of Governor George White. This committee was empowered to receive suggestions for changes or amendments and to report from time to time to the legislature specific recommendations for changes in the Conservancy Act. The committee comprised representatives from the three districts, namely, Judge Robert N. Wilkin, chairman, representing the Muskingum Conservancy District; Honorable Alfred Frank, attorney, representing the Miami Conservancy District;

and W. H. Dittoe, engineer, representing the Mahoning Valley Sanitary District.

As a result of the deliberations and many hearings of this committee, changes and amendments to the Conservancy District Act of Ohio were enacted by the legislature in April, 1937. The committee continued to function a short time thereafter, but due to lack of appropriations very few hearings have been held since then, and no additions or changes in the Conservancy Act of Ohio have been made. In the Act, as amended in 1937, there were included practically all the features originally contained in the Sanitary District Act of Ohio, so that the Conservancy District Act of Ohio may now be utilized for a combination of purposes, representing in the main flood protection, water supply and sewage disposal. One of the additions to the Conservancy Act of a different nature was the requirement that plans of the district should be approved by the Department of Health in so far as water supply, sewage disposal and sanitation were concerned. Likewise, there was inserted the provision that one or more counties could embark upon a program under the Conservancy Act as differing from the original requirement that two or more counties must be involved.

During the late fall and winter months of 1938 and 1939, the authorities of metropolitan Cleveland and of metropolitan Cincinnati simultaneously and independently began to think of utilizing the Conservancy Act for solving metropolitan water supply, sewerage and sewage disposal problems.

In Cincinnati and vicinity the problem involved the construction and operation of sewage treatment plants. The city of Cincinnati developed a plan of sewerage and sewage disposal as early as 1913 and at that time contemplated the construction of the sewerage and sewage disposal features over a period of years as an enterprise of the city, supplemented by contractual relations with the suburban municipalities for sewerage service. The construction of the Mill Creek intercepting sewer was undertaken immediately and during recent years its extension, both up the valley and near the mouth of Mill Creek, has been accomplished by agreement with Hamilton County functioning under the County Sewer District Law. The construction of the Duck Creek intercepting sewer was undertaken jointly on agreement between the cities of Norwood and Cincinnati, with the understanding that when the time came for sewage treatment, supplemental agreements would be made for the building

and operation of said sewage treatment works. In the late summer of 1938, Cincinnati filed with the P.W.A. plans for a project calling for the extension of the Duck Creek intercepting sewer and the construction of a sewage treatment works in the valley of the Little Miami River. This proposal contemplated supplemental contracts with Norwood and other suburban municipalities and established sewer districts of Hamilton County tributary to the Duck Creek sewer. Meetings were held with the representatives of the suburban municipalities involved and there arose the matter of the possible utilization of the Conservancy Act of Ohio for carrying out the construction and operation of the Little Miami sewage treatment project and other sewage treatment projects that would be called for in the metropolitan Cincinnati area. Negotiations are still going on between Cincinnati and the other political subdivisions in the attempt to enter contractual relations that would result in the equitable sharing of the cost of the construction of sewerage and sewage treatment works and the operation of same. In the background there is being considered the alternative of carrying forward this work under the Conservancy Act in the event that mutually satisfactory contractual relations with the various political subdivisions cannot be arranged.

In the Cleveland metropolitan area, the sanitary problem involves the financing of operating costs of existing sewage treatment works, to which are tributary not only Cleveland but ten suburban cities and thirteen villages. There is also the problem of water supply. Cleveland now has two municipal water treatment plants and pumping stations serving ten cities and thirty villages. It is faced with the immediate construction of a new intake, filtration plant and pumping station to supplement the service now being rendered. Further, there is the likelihood that in the near future it will be serving to outside population an amount of water in excess of the 50 per cent extra allowed by Article XVIII, Section 6, of the Ohio Constitution. In other words, there is an operating problem for existing sewerage and sewage treatment works and also a capital outlay and operating problem for existing and proposed water facilities.

Considering the sewerage and sewage disposal problem first, the following are some of the pertinent points. The three treatment plants that have been constructed by Cleveland are now being financed in operation out of sewer rental charges to Cleveland resi-

dents equalling 40 per cent of the water rate schedule. Cleveland has attempted to establish sewer rental charges to the suburbs, which would take into account the suburban share of capital costs and operation charges. Efforts to contract with the suburbs along this line have, however, not met with success. It is for this reason that Cleveland became interested in the possibility of utilizing the Conservancy Act of Ohio as a means of establishing a metropolitan sewerage and sewage disposal district through which fair and equitable charges might be spread over all of the people served by the existing sewerage and sewage treatment facilities. The city council of Cleveland called a meeting of officials of neighboring municipalities to discuss the possibility of setting up under the Conservancy Act such a district for sewerage and sewage disposal purposes. As the result of this general meeting, a subcommittee, comprising legal and engineering talent of the political subdivisions involved, was created. The State Department of Health was asked to send a representative to these committee meetings; likewise, officials of the two existing conservancy districts were invited to attend. In behalf of the two conservancy districts Judge Robert Wilkin, of the Muskingum Conservancy District and chairman of the legislative committee on Conservancy Act revisions and changes, attended the most important of these meetings. As a result of deliberations of the committee, agreement was reached relative to the advisability of setting up a metropolitan district for sewerage and sewage disposal purposes. It was debated whether it would be advisable to create a metropolitan district for water and sewerage purposes similar to those in the vicinity of Boston, Los Angeles and other metropolitan centers; or whether the Conservancy Act of Ohio might be utilized, either in its existing form or with suitable amendments. The committee was unanimous in desiring to proceed along the lines set up in the Conservancy Act of Ohio for the principal reason that legal precedent had already been established, in that the Conservancy Act of Ohio had been upheld in its constitutionality not only by the Supreme Court of Ohio but by the United States Supreme Court.

One of the legal questions involved in the attempt to proceed under the Conservancy Act was the question of whether or not there existed authority at present to establish sewer rentals. The sentiment of the committee seemed to be that it would be necessary to amend the Conservancy Act of Ohio to permit the application of the sewer rental principle (now contained in Sections 3891–1 to 3891–5, inclusive) to apply to conservancy districts.

Another important question was the consideration of ways and means by which the conservancy district, when established, could acquire existing sewerage and sewage treatment facilities, and establish sewer rental rate schedules for amortizing costs of acquiring and costs of operating these facilities. Under the existing Conservancy Act the law contemplates the issuance of assessment bonds or voted bonds for capital outlay. It was the consensus of opinion of the committee that the only practical way to place the district upon a utility basis would be to issue mortgage revenue bonds secured by sewer rentals. A question of constitutionality was raised in that the present authority for issuance of mortgage revenue bonds is vested solely in the municipalities, by Article XVIII, Section 12, of the Ohio Constitution, and no reference is made in the constitution to the issuance of mortgage revenue bonds for any other political subdivision. It was argued by some attorneys that the legislature did not have the constitutional authority to authorize the issuance of mortgage revenue bonds by any political subdivision other than a municipality. Others were of the opinion that such a statute would be constitutional. Finally it was agreed that this could best be decided by a court at law. In order to proceed, and inasmuch as the three sewage plants are built and paid for, the procedure should be the enactment of amendments to provide specific authority to a conservancy district, first, to charge sewer rental and water rates and, second, to issue mortgage revenue bonds secured by revenues. Thereafter a district could be established, charges made to cover the costs of operation, and steps taken to issue mortgage revenue bonds. At that time the constitutionality of the issuance of such bonds could be established by court procedure.

The same arguments that prevail in the matter of establishing and operating a conservancy district for sewerage and sewage disposal purposes prevail in the case of establishment of a similar district for water supply, with the exception that a more immediate prospect is faced in the case of Cleveland for the issuance of mortgage revenue bonds for capital expenditure. As stated previously, the city is in immediate need of a new intake, pumping station and filtration plant if it is to continue to serve the metropolitan area.

One of the items that is of especial appeal to Cleveland and to all of the political subdivisions involved is the possibility, under the conservancy district plan of water supply, of centralizing the authority and establishing a uniform rate to all consumers.

Water Plant Control As Affected by Stream Pollution

By I. N. Carter

THIS paper will deal with a few of the problems met in water plant control, *due to the changing pollutional content of the source of supply.*

It is often asked, "At what pH should a plant be operated?" Someone will reply, "At 7.2 or 7.4"; and another will reply, "at 7.8 or even 8.2." The author would say that the pH control will vary in any plant and may vary hourly. In order, then, to operate the plant at its greatest efficiency, the pH obviously must be varied to meet the changing pollutional contents of the raw water. The questions then naturally arise—what are some of the common variations to be expected and what changes in plant control methods will be necessary in order to meet these pollutional variations. In this paper an attempt will be made to answer these questions in a rather general manner.

The term "pollution" is used here in a relative sense. A water which we like to think of as being a "pure water" contains at least a certain amount of inorganic salts and dissolved gases. A course is considered polluted if the water contains an excess of these compounds or if other substances have entered which will produce a water that is hygienically unsatisfactory or objectionable to the human senses and which would render the supply undesirable for domestic, commercial or industrial use.

Matters which cause stream pollution may be traced to one or more of the following three sources: (1) natural, (2) human and (3) industrial. The nature of the polluting material, coming from these sources may well be classified as organic or inorganic compounds or as certain dissolved gases.

A paper presented on May 11, 1939, at the Pacific Northwest Section Meeting at Tacoma, Wash., by I. N. Carter, Associate Professor, College of Engineering, University of Idaho, Moscow, Idaho.

(1) Pollutional substances coming from natural sources, such as soil erosion; products of organic growth, decay, and oxidation; and pollution caused by the process of leaching out of soluble inorganic salts—are all largely, or entirely, inorganic in nature.

(2) Human and animal pollution which enters a water course is organic in nature. Organic compounds contain large quantities of carbon and nitrogen. During the process of reduction such compounds form stable inorganic salts, large quantities of gases are given off and some of these go into solution. The reduction process is brought about by oxidation and by the digestive action of bacteria and protozoa. Many of these organisms are pathogenic.

(3) Industrial wastes vary materially in composition. They may be either organic or inorganic. A special study should be made of the waste coming from each individual plant in order to determine the composition and nature of the byproduct being disposed of, unless previous determinations have been made.

Inorganic pollution causes, or produces, turbidity, color, taste, odor, hardness, dissolved gases, toxic and poisonous substances, alkalis, acids, etc., and may contain oils, dyes, and other substances which may exert a direct detrimental influence on life or cause a nuisance.

Organic pollution, or the indirect causes of such a pollution, produces a hygienically impure water with disagreeable odors, tastes, color, unsightly appearances and undesirable dissolved gases. It may change the acid or alkaline reaction of the water and tend to reduce the dissolved oxygen content of the stream, which results are quite undesirable.

Dissolved oxygen in a water, whether raw or filtered, is desirable and should not be classified as a pollutional element; although, if the content is high, it would tend to increase corrosion. Dissolved carbon dioxide, hydrogen sulfide, and other gases are undesirable in the finished water. The latter two substances are products of organic decomposition. Oxygen aids in stabilizing organic compounds through direct oxidation, while carbon dioxide and oxygen are necessary aids in supporting bacteria and other forms of life which bring about organic reduction through biochemical action. Dissolved carbon dioxide may cause corrosion.

A few routine tests are used as controls for the proper operation of water plants. Probably the most widely known influences in checking plant operations are the hydrogen ion concentration, or

pH properties, of the water. To these the author added the check tests usually run for bacteria, chlorine, carbon dioxide, alkalinity, and coagulation.

It should be borne in mind that the pH test is a measure of the activity of an acid or an alkali, while the test for alkalinity or acidity measures the total amount of the alkali or acid present.

Figure 1 illustrates the relation between the pH and turbidity of a soft and a hard water. Turbidity would probably range from, say, 50 p.p.m. to 200 p.p.m., while the hardness would vary from about 20 p.p.m. to 200 p.p.m. For this particular water, the optimum pH value was found to be 7.2. For a hard water with high turbidity the proper pH value may run as high as 8.0, while for a soft water with a very low turbidity the pH may best be held at

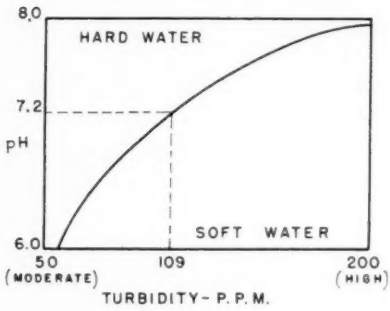


FIGURE 1

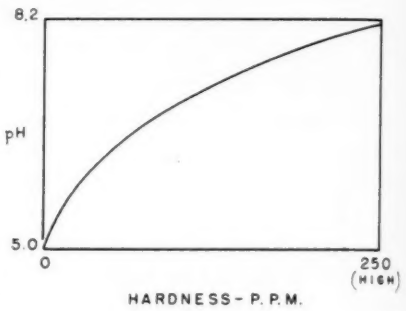


FIGURE 2

about 6.0. It can be seen, however, by referring to Figs. 2, 3, and 4, that other factors enter in, which will affect the ultimate pH values.

Relationship between Hardness and pH

The theoretical relationship between hardness and pH of a water (not considering turbidity or color) is illustrated in Fig. 2. The pH increases with the hardness. A turbid water will tend to increase the pH while the color content of a water will have a tendency to drop the pH value as illustrated in Fig. 3.

The effects of color in a water supply, as just pointed out, are to drop the pH down the scale, as illustrated in Fig. 3. Color is produced by organic compounds which have a tendency toward low pH values. If the organic matter is in a state of putrefaction, the pH values drop still lower. When a water, undergoing treatment,

has both color and turbidity, the treatment process may best be divided into two different stages whereby one substance at a time can best be removed. This process would necessitate a variable pH during the treatment. A hard, colored water may also call for a split treatment with a variable pH value.

The jar test is admirably suited as a practical means of regulating the dosage of chemicals (and the pH) in order to produce the best floc. Figure 4 illustrates the relation between dosage, pH and the quality of floc produced. It should be noticed that a "good" (or satisfactory) floc is produced where the "condition of floc" curve crosses the "dosage curve." To the right of this point the condition of floc curve drops off very sharply. Therefore, little or no good is derived by increasing the dosage. For this particular water, the dosage should be 2.0 g.p.g. with a pH of 7.1. The pH should not

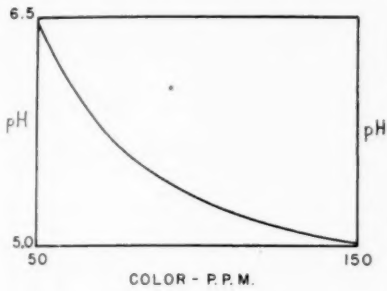


FIGURE 3

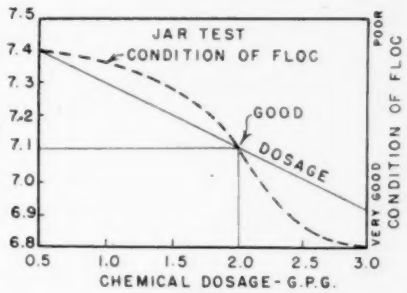


FIGURE 4

be allowed to drop below 7.1 and there would be little or no advantage in maintaining the pH above 7.1.

Corrosion of water pipes is due to the solution of the metal by the water, or by certain physical actions. This discussion is confined to the chemical action of water and metal. Metal in solution forms positive metallic ions. Thus alkalinity and pH are important factors. Dissolved carbon dioxide (and oxygen) in the presence of hydrogen removes certain protective coatings from the pipe, allowing "acid corrosiveness." Thus, carbon dioxide and alkalinity enter into this problem.

It can be seen from Figs. 5 and 6—which illustrate the above principles—that the rate of corrosion is directly proportional to the amount of dissolved carbon dioxide (dissolved oxygen and other factors, to a lesser degree) and inversely proportional to the alkalinity (hardness and other factors, to a lesser degree).

Corrosion of Supply Lines

In order to emphasize the importance of corrosion of water supply pipes, attention is called to the "thumb nail" graph in the lower left-hand corner of Fig. 5. Here is shown the relation between the pH and the per cent loss in the discharge of pipes (due to corrosion) over a period of 30 years. The middle curve of the larger graph represents the line of equilibrium, or the line where a protec-

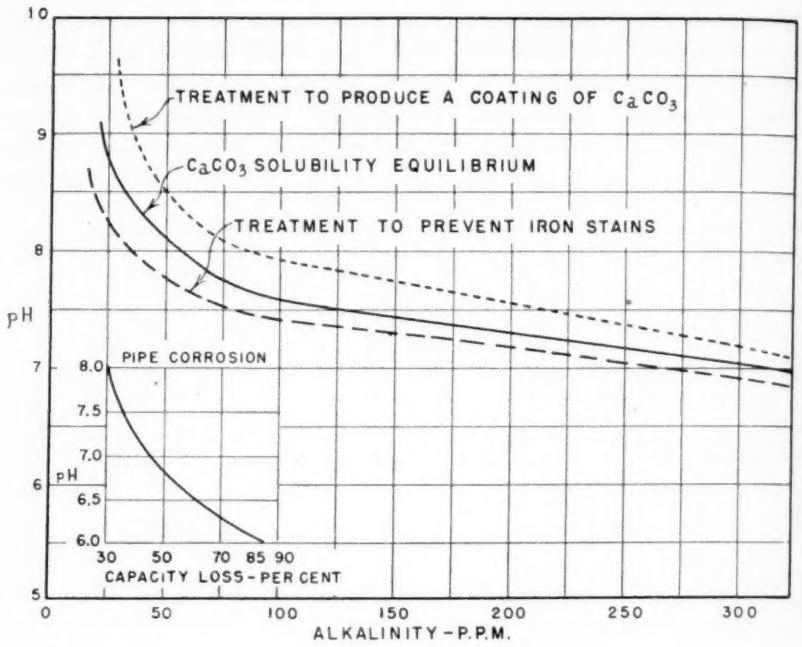


FIGURE 5

tive coating of calcium carbonate is formed. Above this equilibrium curve is the zone of "no corrosion," while the "zone of corrosion" lies above the curve which represents the carbon dioxide values at calcium carbonate equilibrium, Fig. 6. The equilibrium curve of Fig. 5 is superimposed on the curves of Fig. 6. The cross-hatching (shading) of Fig. 6 represents the area of equilibrium between pH, alkalinity and carbon dioxide, or the values at which these three factors should be adjusted in order to prevent corrosion. The pH-alkalinity values would represent another valuable

control test and would vary with the degree and nature of the pollution of the water.

It can be seen from the above discussions that the pH determinations are of prime importance, influencing a wide range of operation controls. It should also be noticed that the factors affecting the pH are hardness, alkalinity (or acidity), turbidity, color, dissolved oxygen, carbon dioxide and many others, all of which depend upon the quality and quantity of pollution.

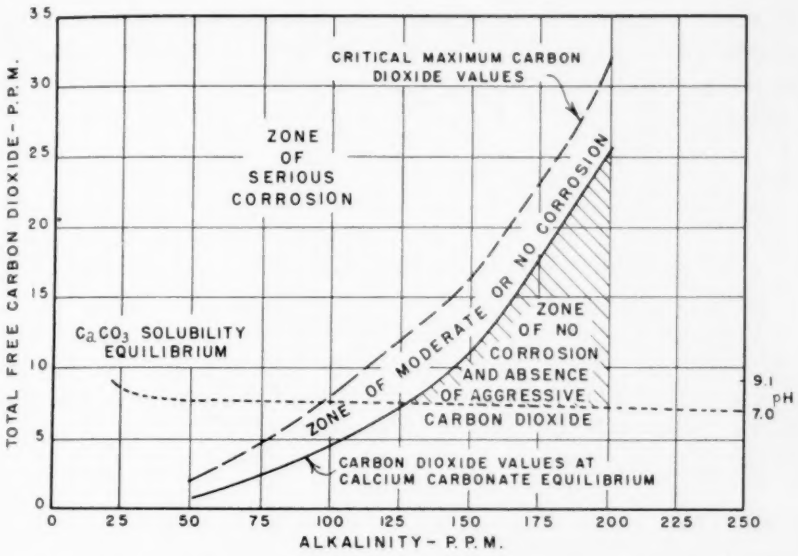

TOTAL FREE CARBON DIOXIDE - P.P.M.
ALKALINITY - P.P.M.
CRITICAL MAXIMUM CARBON DIOXIDE VALUES
ZONE OF SERIOUS CORROSION
ZONE OF MODERATE OR NO CORROSION
ZONE OF NO CORROSION AND ABSENCE OF AGGRESSIVE CARBON DIOXIDE
$CaCO_3$ SOLUBILITY EQUILIBRIUM
CARBON DIOXIDE VALUES AT CALCIUM CARBONATE EQUILIBRIUM
9.1 pH
7.0

FIG. 6. Relationship between Alkalinity, Carbon Dioxide Content and the Corrosiveness of Water

Another important factor to be kept in mind is the effect on the pH of the various pollutional substances. One substance might affect the pH directly while the effect of another would be inverse, in which case a resultant pH value would have to be determined, probably, by experiment. The value would depend upon the degree and nature of pollution and might vary materially from time to time.

Obviously, then, the answer to the question, "At what pH should a plant be operated?" would be: "First, determine the nature and degree of pollution, then by experimental tests (or otherwise) es-

tablish a pH control which would give the best plant operating efficiency." It can readily be seen that the proper pH value might vary seasonally, monthly, daily or even hourly. Also, it might be advisable to operate the plant on a split run, i.e., it might be desirable to remove the color first, turbidity next, etc., in which case the pH would have to be readjusted for each step in the treatment.

Other routine tests which make use of the pH control indirectly are those for bacteria, chlorine, carbon dioxide and dissolved oxygen, alkalinity (or acidity) and a few others of minor importance. It is not within the scope of this paper to include a detailed discussion of such tests, but the ultimate effect of these causes of pollution must be considered in setting up a standard for the operation of a water plant.

Recent Experiences with Carbonaceous Zeolites

By S. B. Applebaum

CARBONACEOUS zeolite, the latest type available to industry, has not replaced the older siliceous zeolites, but it has made a place for itself because of three new properties:

(1) It produces a water of 0 to 2 p.p.m. hardness in either the hydrogen or sodium cycles, i.e., being regenerated either by acid or salt. In the hydrogen cycle, besides removing hardness, it removes alkalinity by changing bicarbonates to carbonic acid, which is then removable by mechanical degasification.

(2) It can remove sodium bicarbonate from water.

(3) It can soften waters low in silica, without the danger of silica pick-up from the zeolite itself.

Three principal users have become particularly interested in carbonaceous zeolites: raw-water ice manufacturers; bottling industry, manufacturing carbonated beverages; and steam boiler users.

This paper will summarize briefly the new experiences in these three fields with actual carbonaceous zeolite installations.

To make clear raw-water ice rapidly, and still not have it brittle, it is essential to use a clear water, low in alkalinity. Hydrogen zeolite is frequently the simplest method of providing such a water. Hydrogen zeolite plants have been installed in ice plants in Texas, Florida and elsewhere with satisfactory results. Table 1 gives the chemical results before and after treatment at several of these plants.

The phenomenal success of the carbonated beverage industry has depended to a great extent on the ability of the average bottler to condition his water supply so as to produce a beverage of constant quality which will not spoil with age.

To accomplish this, the water must be clear, low in color and organic matter, sterile, free from taste and odor, and low in alka-

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linity and total dissolved solids. Therefore, most bottling plants include pressure sand filters (frequently preceded by coagulation tanks), chlorinators, activated carbon taste and odor removers and finally, some provision for alkalinity reduction. Alkalinity reduction is frequently necessary because many soft drinks are prepared

TABLE 1

Some Raw Water Ice Plants Using Hydrogen Zeolite

(Results in p.p.m. expressed as $CaCO_3$)

LOCATION	RAW WATER ANALYSIS		TREATED WATER ANALYSIS	
	Alkalinity	Total Solids*	Alkalinity	Total Solids*
Maryland	460	611	45	196
Florida	142	186	30	74
Texas	243	388	30	175
Missouri	240	292	30	82
Missouri	230	318	20	108

* Total solids here include only sulfates plus chlorides plus alkalinity.

TABLE 2

Some Bottling Plants Using Hydrogen Zeolite

(*Results in p.p.m. expressed as $CaCO_3$*)

LOCATION	RAW WATER ANALYSIS		TREATED WATER ANALYSIS	
	Alkalinity	Total Solids†	Alkalinity	Total Solids†
Texas	235	305	47	117
California	189	392	50	253
California	187	429	50	292
Nebraska	166	265	85	184
Iowa	148	346	50	248
Texas	189	259	40	110
Iowa	300	358	50	108

† Total solids here include only sulfates plus chlorides plus alkalinity.

with extracts that require certain pH values to obtain the desired flavor.

Alkalinity reduction is being accomplished principally at present by either of two methods: lime treatment or hydrogen zeolite. Lime treatment is advantageous when the water needs coagulation and clarification simultaneously with the alkalinity reduction. A considerable number of Spaulding Precipitators have, during the last year, been installed in bottling plants for this purpose. Where

the water comes from wells, however, hydrogen zeolite is frequently preferred because it is less expensive to install and occupies less space. Table 2 gives the water analysis before and after some H_2Z units in the bottling industry.

The field of greatest application of carbonaceous zeolite has been the conditioning of feedwater for steam boilers. Charles W. E. Clarke (1) of the United Engineers & Constructors, Inc., recently described the advances in steam generation, as follows:

"The modern steam generator bears little resemblance to the old-time boiler which was largely a vessel filled with water. . . . To take its place have come elaborate designs of water-walls, economizers, air preheaters, superheaters, and in some cases, reheaters. . . .

"Coincident with the initial trend toward high steam pressures, which occurred over a decade ago, the problem of feedwater treatment attracted the attention of many able chemical engineers. . . . Without the accomplishments of these specialists, operation of the modern steam generator in many cases would be impossible. One of the great surprises that comes to managers of industrial plants facing expansion of the steam facilities is learning that water which was perfectly suitable for the old low pressure boilers requires some special form of treatment for the new equipment. Yet no problem is more important to the engineer in this field than boiler feedwater treatment."

Modern practice in feedwater conditioning usually calls for:

1. Prevention of scale or other boiler deposit
2. Prevention of corrosion
3. Prevention of deposits in turbines, super-heaters or other steam equipment
4. Prevention of corrosion in return lines
5. Inhibition of embrittlement

To accomplish these results, the usual water conditioning plant includes:

(1) For scale prevention—clarification and water softening equipment followed by addition of phosphates or other secondary treatment added to maintain a concentration of PO_4 or similar reagent in the boilers themselves. In some cases, silica removal equipment is being installed.

(2) For corrosion prevention—suitable deaerators followed by sodium sulfite or other similar secondary treatment to maintain a

concentration of sulfite in the boilers. Also pH control is frequently practiced to protect the feed lines. Partridge and Hall (2) have indicated that reduction of alkalinity reduces corrosion at "hot spots" in boiler tubes.

(3) For prevention of deposits in the steam system—continuous boiler blowoff equipment is installed to control the concentration of total solids in the salines of the boilers below the safe carry-over limit. In addition, the alkalinity is reduced because lower alkalinity usually results in drier steam. Straub (3) has indicated that turbine deposits are frequently prevented by reducing the alkalinity.

(4) For prevention of return line corrosion—proper deaeration of feedwater plus reduction of alkalinity is being practiced. The alkalinity (bicarbonates plus carbonates) splits up in the boiler to form caustic soda and CO_2. The latter is carried off with the steam and when the steam is condensed, the CO_2 goes into solution in the condensate and reduces the pH to low values. These low pH values cause acidic corrosion in the condensate pipe lines, especially if some dissolved oxygen is also present. Deaeration removes the oxygen from the feedwater, so that the steam is usually oxygen-free. But in the steam-using equipment oxygen may be drawn in, as in radiators, condensate storage tanks, etc. The combination of oxygen and high CO_2 content is very corrosive. In some cases, the alkalinity has been reduced to zero to get rid of all of the carbonates before the heater. After the heater, some caustic soda is added to raise the pH value to prevent corrosion of the feed system and the boilers, and yet produce a steam containing a minimum of CO_2. J. H. Walker (4) of the Detroit Edison Company has described the steps taken by that company to use additional acid after sodium zeolite so as to reduce the alkalinity of the feedwater to a minimum to prevent return line corrosion. The acid converts the bicarbonates to sulfates and free CO_2. This CO_2 is reduced by a degasifier, so that the deaerator which follows removes the residual CO_2 fairly completely. Thus the steam finally produced is low in CO_2 content.

(5) For inhibition of embrittlement—the usual A.S.M.E. sulfate-carbonate ratios are still being maintained by the great majority of users, although the A.S.M.E. Code may in the future undergo some changes for welded boilers of higher pressure.

In deciding on the type of treatment to prevent scale and sludge deposits in the boiler, etc., it is usually necessary to compare first cost, operating cost, space requirement, amount of boiler blowoff

and chemical analyses of effluents of the various primary treatments available. These primary treatments to be compared usually are:

(1) Hot lime soda, with or without external phosphate finishing treatment, and with or without acid treatment to follow.

(2) Sodium zeolite, with or without acid treatment to follow.

(3) Cold lime, with or without soda ash plus carbonation or acid, plus sodium zeolite (carbonaceous) alone or plus sodium and hydrogen zeolite.

(4) Sodium plus hydrogen zeolite (carbonaceous).

Secondary internal treatments in the boilers themselves, such as phosphate, sulfite, or other similar reagents, are usually added to all these four primary treatments.

In general, hot lime soda is less expensive for harder and turbid waters, because sodium and hydrogen zeolite plants increase in cost with the cations to be removed, whereas hot lime soda increases in cost merely with flow rate. Sodium zeolite alone is adapted for waters of fairly low hardness and total solids. Cold lime plus zeolite, and sodium plus hydrogen zeolite, despite greater first cost, have been making steady progress during the last few years. It is becoming realized that these two types of treatment are the next best treatments to distillation to produce an effluent of nearly zero hardness, with as low an alkalinity as may be desired, and with the lowest possible total solids to keep boiler blowoff at a minimum. Figure 1 gives a general graphic comparison of the results produced by Methods 1, 2, and 4.

Cold lime zeolite is favored for high alkalinity surface waters also high in turbidity and silica. Hydrogen zeolite is preferred for clear high alkalinity waters of medium chloride, sulfate and silica content and especially for sodium bicarbonate waters.

A factor that led to the installation of many hydrogen zeolite units is the ease with which they may be added to existing sodium zeolite plants. When a boiler plant that has been using sodium zeolite units is about to be expanded either by more boilers of the same pressure or by the addition of a topping boiler of larger capacity, the user may either add more sodium zeolite units and additional secondary treatments, or he may add hydrogen zeolite units that will both increase the total capacity and reduce the alkalinity and the total solids of the effluent. The hydrogen zeolite units are more expensive due to the special rubber-lined parts required, but the added investment is usually returned in a short period by virtue of the superior quality of the effluent.

The following cases are typical of the operating experiences with carbonaceous zeolites in the boiler field.

Case 1: Power Plant in Midwest (Hydrogen plus sodium zeolite)—Two boilers, pressure designed for 525 lb./sq.in. but operating at 475 lb./sq.in.; boilers of two-drum type with self-contained integral water-wall tube furnace; evaporation 400,000 lb./hr.; makeup 100 per cent.

The water supply in this case is a clear city supply. The city filters a river water in the municipal filtration plant. It varies in

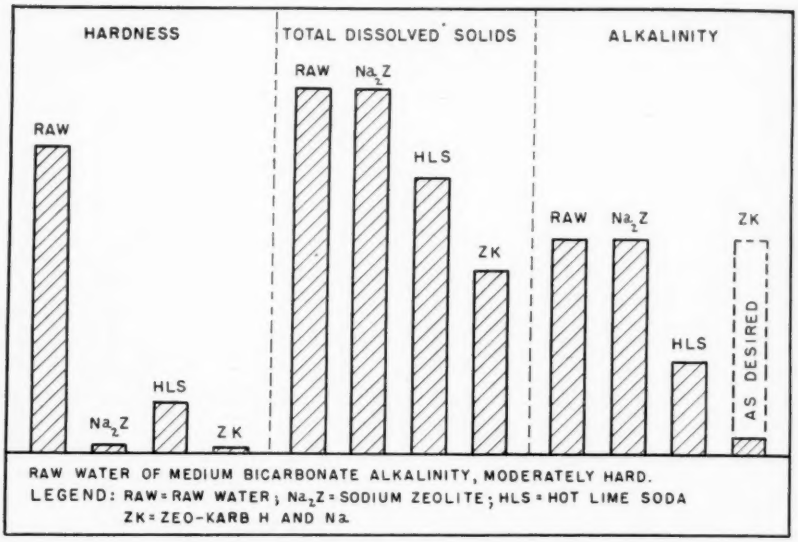

FIG. 1. Results of Treatment

composition appreciably from season to season. Nevertheless, the control of the treatment has been constant, despite the raw water variations. The plant consists of:

Zeo-Karb Na.....	2 units	90 in. diam. x 11 ft. high
Zeo-Karb H.....	2 units	84 in. diam. x 11 ft. high
Degasifier.....	1 unit	15 ft. diam. x 20 ft. high

The alkalinity of the sodium zeolite effluent is utilized to neutralize the acidity of the hydrogen zeolite effluent to produce a mixed effluent of about 15 p.p.m. alkalinity. About 43 per cent of the flow passes through the hydrogen zeolite and about 57 per cent through

the sodium zeolite. Table 3 gives typical chemical results. The alkalinity in the mixed effluent is quite uniform throughout the 24 hours usually varying not over ±3 p.p.m. The degasifier reduces the 158 p.p.m. of free CO_2 shown in the mixed effluent in Table 3 down to under 5 p.p.m. at all times, so that the deaerating heater removes the CO_2 completely.

TABLE 3

Illustration of Case 1

(Results in p.p.m.)

	RAW	ZEO-KARB H	ZEO-KARB Na	43% ZEO-KARB H, 57% ZEO-KARB Na
Total Hardness as $CaCO_3$	337	0–1	0–3	0–2
Calcium " " "	200	0–1	0–2	0–1
Magnesium " "	98	0	0–1	0–1
*Alkalinity " "	194	0	194	15
Carbon Dioxide " CO_2	—	170	—	158
*Chloride " NaCl	29	29	29	29
*Sulfate " Na_2SO_4	320	320	320	320
Chloride " $CaCO_3$	25	25	25	25
Sulfate " "	225	225	225	225
Theoretical mineral acidity as $CaCO_3$		250		
Free Mineral Acidity as $CaCO_3$		222		
Silica as SiO_2	12	12	12	12
Total Solids (Items *)	543	349	543	364

Figure 2 gives the general design of the degasifier that has been developed after some research to give these low CO_2 contents despite low winter temperatures. It involves two features:

(1) The staggered slat tray construction subdivides the films of water, always exposing new water surfaces to the air and insuring efficient degasification in a small space.

(2) The air flows counterflow to the water, so that the falling water continually enters air spaces containing lower and lower partial pressures of CO_2. Since the solubility of a gas in water decreases with the partial pressure of the gas in the air space, the CO_2 in the final effluent is low with a minimum of air used.

Case 2: Paper Company of Tennessee (Hydrogen and Sodium Zeolite)—This represents a case of a low pressure boiler plant using an existing sodium zeolite plant which was modernized early

in 1938 by the installation of higher pressure boilers. At the same time a hydrogen zeolite unit was installed to supplement the older sodium zeolite treatment. The softening plant consists of:

Sodium Zeo-Dur.....	2 units	84 in. diam. x 6 ft. high
Zeo-Karb H.....	1 unit	84 in. diam. x 7 ft. high
Degasifier.....	1 unit	9 ft. diam. x 16 ft. high

The older boiler plant consisted of 10 boilers, 150 lb. pressure, 3,200 rated h.p. Eight of these were replaced by three 400 lb.

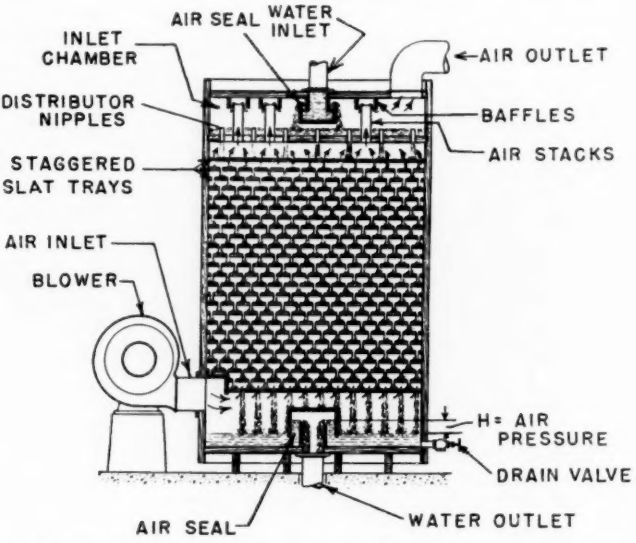

FIG. 2. Section Through Permutit Degasifier; arrows indicate air flow

pressure integral furnace type boilers. The evaporation is about 250,000 lb./hr.; makeup is 40 per cent.

Phosphate and sodium sulfite are pumped directly to the boiler drums. A continuous boiler blowoff system maintains uniformly low concentrations.

The source of supply is a river water, clarified by the general mill filter plant. Table 4 gives typical chemical results before and after treatment. About 43 per cent of the flow passes through the old twin unit sodium zeolite and 57 per cent through the hydrogen zeolite.

There has been no scale found in these boilers on the inspections made every six months. The boiler blowoff was reduced about 50 per cent as compared with the previous sodium zeolite experience because of the lower total solids.

Case 3: Central power plant in the East (Zeo-Karb H & Na)—This central power station had been operating with the usual 2 to 3 per cent makeup with surface condensers, etc. A topping boiler installation was decided upon for the recent expansion of this plant

TABLE 4

Illustration of Case 2

(Results in p.p.m.)

	RAW FILTERED	ZEO-KARB H	ZEO-KARB Na	57% H & 43% Na AFTER DEGASIFIER
Total Hardness as $CaCO_3$	90	0–1	0–3	0–2
Ca " " "	58	0–1	0–2	0–1
Mg " " "	32	0	0–1	0–1
*Alkalinity " "	80	0	75	13
Free CO_2 " CO_2	5	75	5	4
*Chlorides " NaCl	8	8	8	8
*Sulfates " Na_2SO_4	40	40	40	40
Total Solids (sum of *)	128	48	123	61
Free Mineral acid as $CaCO_3$	—	40	—	—

TABLE 5

Illustration of Case 3

(Results in p.p.m.)

	RAW	AFTER ZEO-KARB H	AFTER ZEO-KARB Na	MIXTURE 56% H_2Z 44% Na_2Z	AFTER DEGASI-FIER	AFTER NaOH
Total Hardness as $CaCO_3$	44	0 to 2	0 to 5	0 to 3	0 to 3	0 to 3
*Alkalinity " "	32	0	29	4	4	8
Free CO_2 " CO_2	4	32	4	20	4	0
*Chlorides " NaCl	5	5	5	5	5	5
*Sulfates " Na_2SO_4	21	21	21	21	21	21
Acidity " $CaCO_3$	0	16	0	0	0	0
*SiO_2	6	6	6	6	6	6
pH	7.0	3.5	7.0	5.0	6.0	8.5
Total Solids (items *)	64	32	61	36	36	40

and at the same time, bled steam was to be discharged into central steam mains for central heating. This increased the per cent of makeup to 25 per cent.

The water supply is a municipal water of fairly low total solids. Hitherto internal boiler treatment had sufficed to keep the boilers

clean, due to the low per cent of makeup, but the increased makeup requirements and the high boiler pressure (1,250 lb./sq.in.) made external water treatment desirable. At the same time, the use of the bled steam for central heating made it necessary to insure low CO_2 in the steam to prevent return line corrosion.

The final specifications, therefore, called for an effluent of minimum total solids and hardness, as well as a minimum carbonate or bicarbonate alkalinity. In fact, an alkalinity approaching zero was preferred. Zeo-Karb H plus Na fulfilled these requirements most closely. The softening plant consists of:

Zeo-Karb Na.....	2 units	11 ft. diam. x 7 ft. high
Zeo-Karb H.....	2 units	12 ft. diam. x 6 ft. high
Degasifier.....	1 unit	14 ft. diam. x 18 ft. high

The makeup requirement for the initial Zeo-Karb installation is about 600,000 lb./hr. but space and connections have been allowed to add a third sodium and a third hydrogen unit to increase the capacity to 1,200,000 lb./hr. of treated makeup.*

The average analyses of the raw water, the effluents of the hydrogen and sodium units, the mixed water, and the degasifier effluent are given in Table 5. Caustic soda is to be fed after the degasifier to raise the pH to between 8.5 to 9.0.

The trend in steam boiler design is definitely towards higher pressure. As an illustration of this, Sheppard T. Powell (5) has indicated that 130 high pressure boilers (400 to 2,500 lb./sq.in.) were installed between January, 1936 and September, 1937. The trend has been made possible by a simultaneous advance in the art of feed water conditioning, and the use of carbonaceous zeolites.

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* In March, 1940, these additional units were purchased.

Use of Granular Activated Carbon at Bay City

By Louis B. Harrison

THE progress made in the field of taste and odor removal from water has been considerable when it is realized that only slightly over a decade ago no satisfactory treatment of wide application for obtaining a taste-free water was known. The introduction of powdered activated carbon has resulted in most cases in an effective and reliable treatment. Originally, granular carbon was tried on a small scale but owing to the ease with which the powdered carbon can be applied and because of the small initial financial outlay involved, most efforts have been concentrated on its study, application and methods of evaluation.

While powdered carbon with the improvement in methods of activation has been doing a splendid job, it has failed in certain cases to produce entirely satisfactory results, e.g. in Bay City and Saginaw. Experimental and actual plant results have shown that where treatment with powdered carbon has not been entirely satisfactory, granular carbon when resorted to, has solved the problem. As in the application of powdered activated carbon, so also in the application of granular carbon, pioneering work had to be done. While the granular has been used in small installations in household filters and in industrial plants, large scale installations in water purification plants are still few. As far as can be found, the first large installation was placed in service in the Bay City filtration plant in 1930. A short time later, Dundee, Mich., installed a carbon unit to remove sugar-beet waste odors. Since then, the Bay City plant has increased its granular carbon unit capacity to 8 m.g.d. Culver City, Calif., has a 1.25 m.g.d. unit. Plants with granular carbon units have been installed in Oshkosh and Neenah, Wis.; new system of small capacity

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in Frankenmuth, Mich., is installing such units; and in European countries there is also considerable activity with the granular carbon. Apparently, then, the installation of such units is growing and a need for detailed study and specifications on the carbon and methods for its evaluation are becoming of importance.

It is the purpose of this paper to relate plant and laboratory experiences with granular carbon since 1930 in Bay City.

When Baylis published his paper "Carbons and Their Uses in Removing Objectionable Tastes and Odors from Water" (Jour. A. W. W. A., **21**: 787 (1929), the writer became extremely interested,

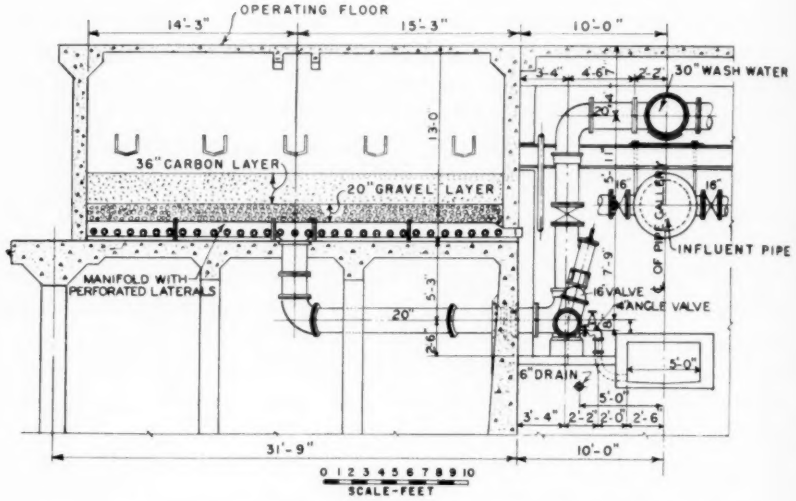

FIG. 1. Section through Carbon Units, Bay City, Mich., Filter Plant

since super-chlorination and de-chlorination, chlorine-ammonia and permanganate treatments failed to do effective work. The taste problem in Bay City water is a result of industrial wastes from chemical industries, oil fields, oil refineries, sugar beet factories, sanitary sewage, and algae tastes and odors. These tastes occurring intermittently, are of varying intensity, and their duration varies from one day to several months. Tastes of lesser intensity are almost always present.

After a short period of experimentation one of the sand filters was converted into a granular carbon unit (Figs. 1 and 2). The sand was removed as far as possible and replaced with 1,400 cu.ft. of

granular Hydrodarco 4 x 10 mesh, producing a layer 24 in. deep. Special fittings and pumping facilities were installed so that the effluent of the sand layer could be lifted to the carbon and maintained at a certain level. The granular layer is simply one of the former sand filters in which the sand has been replaced with carbon. Since this first installation, two additional filters have been similarly converted into carbon units. In two units, the original carbon has been removed and replaced with Granular Norit, 36 in. deep, and the rate of filtrations has been changed from 2 to 3 g.p.m. per sq.ft. One of

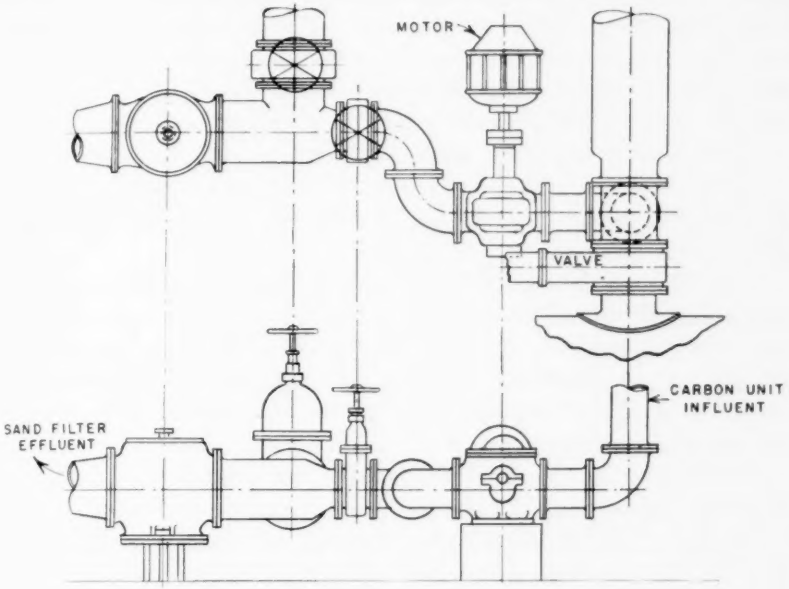

FIG. 2. Detail of Design of Bay City, Mich., Filter Plant

the granular carbon units installed in 1935 still has the granular Hydrodarco and is filtering at the rate of 2 g.p.m. per sq.ft.

Originally a mixed water was supplied to the consumer, on the basis that when the threshold odor had been reduced sufficiently, the water would be satisfactory. It was soon discovered, however, that only water entirely free of taste and odor would meet with public approval, so the whole supply is now passed through carbon units for the majority of the year.

From a short period of experimentation, it was concluded that one cubic foot of granular carbon would be sufficient for 1 g.p.m. per

sq.ft. rate of filtration. This question, however, needs further study. After the whole supply had been passing through the carbon units it was discovered that taste would re-occur in the mains in spite of the fact that a very reliable operator, delegated to taste the water hourly at the plant, failed to detect the slightest taste in the treated water. Post-chlorination had been reduced to .01 p.p.m. residual at the plant. Water in the wash water tank when first filled was free of taste; however, within 24 hours a slight taste would develop. On this basis it was concluded that certain waters, at least the one handled at the plant, require an excess carbon treatment.

The treatment at present consists of reducing the taste with powdered activated carbon to as low a threshold odor as possible and then passing the conditioned filtered water through the granular carbon units. This treatment results in a water that is entirely free of objectionable taste and odors and also a water stable, as far as tastes are concerned, in the city mains. The final effluent is treated with chlorine ammonia, and the residual chlorine is maintained at .07 to .08 p.p.m.

In order that the carbon layers may function properly it is necessary to condition the water. The water is pre-chlorinated, softened and well settled. In the Bay City plant, where the sand filter effluent has to be lifted to the carbon units, it is imperative that irrespective of the amount, the floc be well formed. The water leaving the sand filter should be free of all turbidity.

Washing of the granular carbon has been a problem. A normal wash cannot be applied because of loss in carbon and in particular in the fines. It has been found that the most efficient method of washing is to use half the normal wash rate. While the wash water is applied, the operator uses a rake working it up and down until the carbon throughout the bed is well stirred. It is surprising to observe the succession of odors liberated in this manner. The wash is continued for two minutes after no odors are detected. How frequently granular carbon should be washed in this manner depends on local conditions; twelve a year are sufficient at the Bay City plant. If the water is well conditioned, the loss of head on a carbon layer is negligible. Since the last wash the carbon units have been in service 2,512 hours up to May 2, 1939 with no noticeable change in loss of head, the gage registering 0.5 ft.

The problem of placing a carbon of low density in the filter produced a great deal of concern. This was solved by first wetting the

carbon with a hose until the possibility of dust formation had been removed and then applying full force. In this manner it was possible to get almost 99 per cent of the carbon to settle. Hourly stirring sank the small amount of floating matter. It appears that the question involved is not the relative densities of the carbons but their "wettability."

A. S. Behrman of the International Filter Co. made many suggestions which were the basis for much of the laboratory procedure. Instead of conducting the experiments in terms of unit volumes, which was previous practice, the author modified the procedure by using a unit weight.

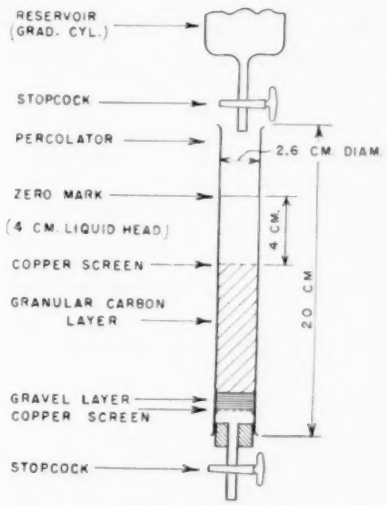

FIG. 3. Apparatus Used in Determining the Relative Activities of Granular Carbon Units

The apparatus used is shown in Fig. 3. A phenol solution of known strength (250 p.p.m.) was passed through a layer of a definite depth and weight maintaining a constant head and a uniform rate of flow of 1 liter per 30 min. The phenol remaining in the filtrate was determined in the usual manner by precipitation as tri-bromophenol, the excess bromine being converted to iodine and titrated with N/10 thiosulfate using starch as an indicator.

$$250 - (\text{c.c. N/10 bromate-bromide} - \text{c.c. N/10 Thio.}) \times 15.67 \times \text{Vol. of effluent in liters} = \text{p.p.m. of phenol removed}$$

The first experiment made attempted to discover a relationship between particle size and phenol removal. The purpose was to determine the most efficient size of granular carbon particle. Carbon of a 4x10 mesh was ground up to various sizes and their phenol removal capacity determined. Figure 4 shows the results. The value of a smaller size particle or granular carbon is demonstrated.

DATA FOR FIG. 4

Rate of flow: 1 liter per 30 minutes
Concentration of phenol solution: 200 p.p.m.
Diameter of layer: 2.6 cm.
Depth of gravel: 1.5 cm.

GRANULAR CARBON	MESH	WEIGHT OF CARBON	DEPTH OF LAYER	PHENOL REMOVAL
		grams	*cm.*	*per cent*
Carbon R	4 x 10	6.8	6.0	45.4
	8 x 10	7.6	6.0	50.8
	10 x 20	8.5	6.0	80.8
	20 x 30	9.5	6.0	100.0
	30 x 40	10.0	6.0	100.0
	40 x 50	11.0	6.0	100.0

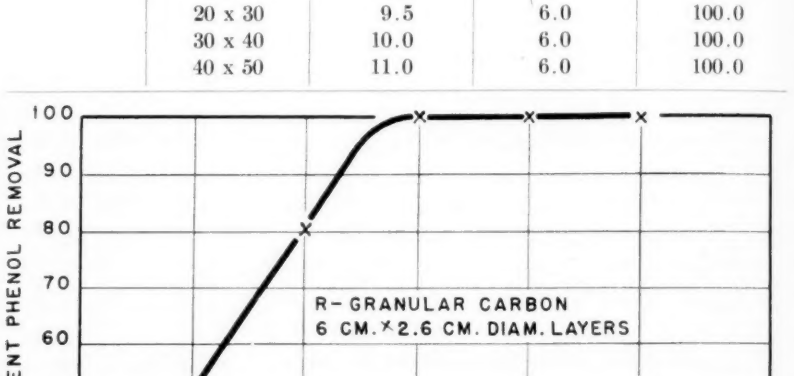

FIG. 4. Particle Size vs. Phenol Removal (see data above)

A second experiment was designed to test the phenol removal of two carbons in the form received, and after they had been ground to smaller size particles. Carbon B 4x12* mesh and Carbon R 4x10 mesh were used. Figures 5 and 6 show the results.

* In this and the following carbon designations, the letter refers to the trade name of the carbon, and the figures to the size of the particles. 4 x 12

Carbon R 4x10 mesh removed less phenol on a volume basis than Carbon B 4x12. On a weight basis, however, Carbon R removed

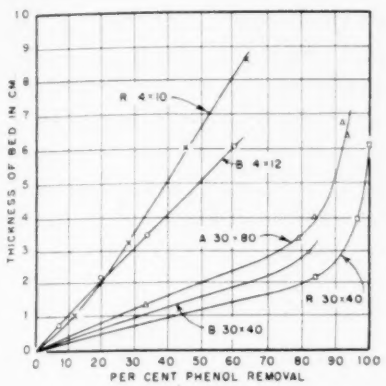

FIG. 5

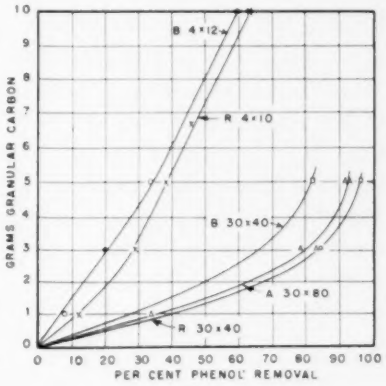

FIG. 6

FIG. 5. Phenol Removal by Granular Carbon Layers
Diameter of layer: 2.6 cm.
1 liter (250 p.p.m.) phenol solution passed in 30 min.

FIG. 6. Phenol Removal by Granular Carbon Layers
Concentration of phenol solution: 250 p.p.m.
Diameter of layers: 2.6 cm.
Depth of gravel layers: 1.5 cm.
1 liter of phenol solution passed in 30 min.

TABLE 1

Analysis of Carbons

	B 4 x 12	R 4 x 10
Moisture	5.45 per cent	6.00 per cent
Ash	27.4 " "	3.00 " "
Volatile	5.26 " "	3.00 " "
pH	3.1 " "	10.5 " "
Approx. Density	.55 " "	.49 " "

more phenol than Carbon B. Also when reduced to smaller particles Carbon R 30x40 removed more phenol than Carbon B 30x40, both on weight and volume bases. The analysis and screen tests shown in Tables 1 and 2 demonstrate the entirely different structure of the two carbons.

means that the carbons will go through mesh 4 but be retained on mesh 12. This method of designation is consistent through the remainder of the paper.

Use of Large Particles as Substratum

Attempts were then made to determine whether it might be possible to use different sizes of carbon, employing the heavier particles as a substratum and superimposing the lighter particles, then using the layer until the lighter particles were exhausted, finally removing them by backwashing. It was therefore determined what amounts of the smaller products would be necessary to have the same phenol removing power of 10 grams of carbon 4x10. The smaller particles were produced by grinding 4x10 particles and screening them. Fig. 7 shows the results. A much smaller amount of carbon can be used with this method.

TABLE 2

Screen Test of Carbons

SCREENS	B 4 x 12		R 4 x 10	
	grams	*per cent*	*grams*	*per cent*
on 4	5.50	4.5	1.21	.8
4 x 6	14.90	13.0	80.30	55.0
6 x 8	31.65	27.6	44.20	30.3
8 x 10	18.30	15.9	2.43	1.7
10 x 16	35.42	31.2	3.81	2.6
16 x 20	5.00	4.4	2.96	2.0
20 x 30	1.54	1.3	1.56	1.1
30 x 40	.84	.7	2.45	1.7
40 x 50	.41	.4	1.33	.9
through 50	1.68	1.5	5.52	3.8
Total.....	114.89	100.5	145.77	99.9

An experiment to test the backwashing of smaller particles from a sub-stratum of larger ones was performed to determine whether 8x20 mesh, 30x40 mesh, or 30x80 mesh carbon could be backwashed off 4x10 carbons. The apparatus used was simply a glass cylinder, 3 in. in diameter by 10 in. high, supported vertically and arranged so that the wash water entered at the bottom and overflowed at the top. Varying amounts of the above mentioned fine carbons were placed on a 4x10 carbon substratum. Fairly high rates of backwashing (approximately 20 liters per 30 min.) were used without materially displacing the 4x10 carbon base. The separation or "floating off" of the fine carbons was also very easily effected when

the fine carbons were mixed with the 4x10 carbon instead of being placed on the top of it. A little higher rate of backwash was, however, necessary.

DATA FOR FIG. 8

Concentration of phenol solution: 250 p.p.m.
Rate of flow: 1 liter per 30 min.
Diameter of layers: 3.2 cm.
Depth of gravel layers: 4.1 cm.
Weight of carbon used: 10.0 gms.

TREATMENT	GRANULAR CARBON	MESH	DEPTH OF CARBON LAYER	PHENOL REMOVAL
			cm.	*per cent*
One liter of Phenol Solution passed through layers	Carbon R	4 x 10	5.6	67.2
	Carbon B	4 x 12	3.9	56.3
Above layers washed with liters of water, then 1 liter of Phenol solution passed through	Carbon R	4 x 10	5.6	56.3
	Carbon B	4 x 12	3.9	45.0
Above layers again washed with 5 liters of water and 1 liter of Phenol solution passed through	Carbon R	4 x 10	5.6	53.7
	Carbon B	4 x 12	3.9	42.8

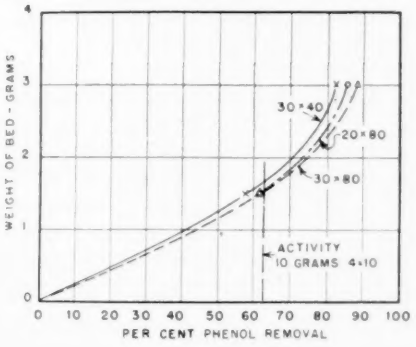

FIG. 7

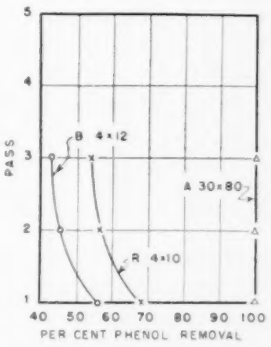

FIG. 8

FIG. 7. Use of Larger Particles as Substratum—Weight Basis
FIG. 8. Drop in Carbon Activity

The next item in the procedure was to determine whether carbon is actually exhausted when a strong phenol solution has passed through it. To determine this, 10 grams of carbon were used and a

phenol solution (250 p.p.m.) passed through it. After determining the amount removed, the carbon was washed with 5 liters of distilled water and another liter of phenol passed. This was repeated a second time. The results are shown graphically in Fig. 8. It would have required too much time to conduct the experiment to a point where total exhaustion would take place. There must be drawn a distinction between the exhaustion of carbon and the apparent exhaustion.

A comparison of phenol removal from dilute solution by powdered activated carbon and granular carbon was made. A suspension of 100 p.p.m. of powdered carbon was prepared with carbon-treated

TABLE 3

Comparison of Phenol Removal

POWDERED CARBON			GRANULAR CARBON		
P.p.m. carbon	P.p.m. phenol remaining	P.p.m. removed for each additional 10 p.p.m.	Carbon	P.p.m.	Phenol remaining
1	.88				
10	.59	.27	R 4 x 10	100	.08
20	.41	.18	B 4 x 12	100	.09
30	.31	.10	A 30 x 80	100	.045
40	.25	.06	R 40 x 50	100	.033
50	.15	.10			
60	.10	.05			
70	.063	.037			
80	.049	.014			
90	.039	.010			
100	.034	.005			

distilled water. Various concentrations of carbon were made from the suspension and diluted to one liter. Then 1 c.c. of phenol solution (997 p.p.m.—determined by bromination) was added to the carbon suspension. The round bottom flask was placed in a shaking machine for two hours (about 150 cycles/min.). The suspension was filtered and the remaining phenol determined. In the case of granular carbon, 0.2 grams of each of the various granular carbons were placed in three-liter beakers with two liters of 1 p.p.m. phenol solutions. The solutions were then agitated for one hour. After filtering, the phenol concentration of the filtrates was determined by the Gibbs method as shown in Table 3. The results show that a

granular carbon of a definite size is just as efficient as a powdered carbon on dilute phenol solutions and that the removal of traces of phenol with powdered carbon becomes quite expensive. The powdered carbon used is still highly active. Whereas in the case of granular carbon it is used over and over until near exhaustion, in the

TABLE 4

Phenol Removal by Granular Carbon Layers (30 x 40 Mesh) and Rejuvenation of Such Layers with Potassium Permanganate Solution

TREATMENT	GRANULAR CARBON	MESH SIZE	WT. OF CARBON GMS.	DEPTH CARBON GMS.	PER CENT PHENOL REMOVAL
1. One liter of phenol solution passed through layers. Rate of flow: 1 liter/30 min.	Carbon A	30 x 80	3.0	3.3	79.2
	Carbon R	30 x 40	3.0	2.1	84.0
2. One liter of phenol solution passed through above layers. Rate of flow: 1 liter/30 min.	Carbon A	30 x 80	3.0	3.3	38.1
	Carbon R	30 x 40	3.0	2.1	45.8
3. One liter of phenol solution passed through above layers (third pass.) Rate of flow: 1 liter/30 min.	Carbon A	30 x 80	3.0	3.3	9.3
	Carbon R	30 x 40	3.0	2.1	11.0
4. One liter of 0.005 *N* $KMnO_4$ solution passed through layers after treatment #3. 1 liter 20/min. Layers washed with one liter distilled water —1 liter/15 min. One liter phenol solution passed through beds—1 liter/30 min.	Carbon A	30 x 80	3.0	3.3	37.7
	Carbon R	30 x 40	3.0	2.1	34.3

Concentration of phenol solution: 250 p.p.m.
Diameter of layers: 2.6 cm.
Depth of gravel layers: 1.5 cm.

case of powdered carbon the excess is wasted. Where substances in low concentrations produce objectionable tastes and odors and an excess carbon treatment must be resorted to in order to produce a water that will be taste and odor stable in the mains, the granular carbon is less expensive.

The possibility of using an oxidizing agent to re-activate a granular

carbon layer was next considered. A series of experiments has been conducted for this purpose with results as shown in Table 4. Permanganate has some value as a re-activator and its use in activating carbons may be something worth trying. It is also interesting to

DATA FOR FIG. 9—in p.p.m.

SAMPLE	PHENOL REMAINING IN SOLUTION	PHENOL TAKEN UP BY CARBON	PHENOL IN WATER	PHENOL REMAINING IN CARBON
1	68	198	42	156
2	136	130	70	216
3	150	116	92	240
4	168	98	86	252
5	160	106	92	276
6	168	98	97	277
7	165	101	92	286

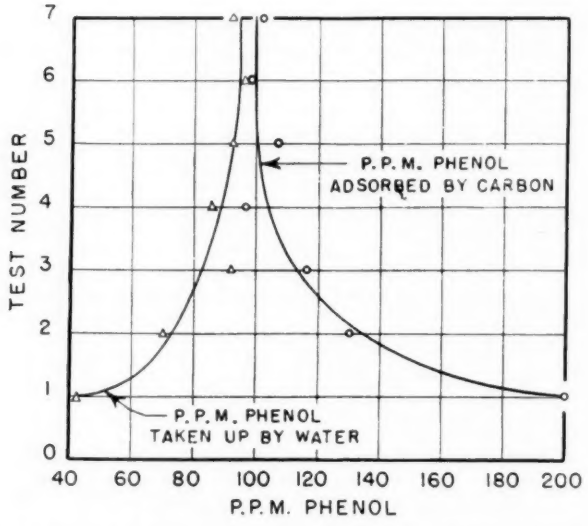

FIG. 9. The Reversibility of a Granular Carbon Layer

note that Carbon A 30x80 re-activated better than Carbon R 30x40. Carbon R, however, was originally more effective in phenol removal.

Nearly exhausted granular carbon B 4x12, which has been in use for five years, has been re-activated by heat treatment with very good results. The carbon was actually restored to its original phenol number. A thousand pounds of carbon has been re-activated by the use of high temperature (800°C.). In the re-activation process a

5 per cent loss has been experienced and the total cost per pound averaged five cents. It is believed that re-activation can be done in connection with the plant thereby greatly reducing the cost. The actual re-activation has been done at the experimental plant of the Dow Chemical Company of Midland, Mich. The cost of constructing a re-activation plant would be nominal.

To determine whether it is possible for a carbon layer to reverse itself, a liter of 226 p.p.m. phenol solution was passed through a ten-gram layer of Carbon R 20x80 mesh. This was followed by a liter of distilled water using the same rate of flow. The phenol concentrations of the effluents were determined. Like treatments followed successively until the phenol concentration in effluents, both phenol solution and water, reached a constant figure. Figure 9 shows the results. At no time did the concentration of the phenol in the water exceed the phenol taken up by the carbon, showing that there was no reversal. The tendency of the carbon, rather than to reverse itself, is to spend itself as to adsorptive power. As used, the term "reversibility of a carbon layer" means the tendency of carbon to give up impurities at a faster rate than it adsorbs them from a given solution.

Conclusion

From the laboratory research and years of plant experience with granular carbon, it has been concluded that:

(1) Where intensive taste and odor problems are experienced in a water supply and excessive amounts of powdered carbon have to be applied, the use of granular carbon must be considered;

(2) Where granular carbon units are in use, provisions should be made for powdered treatment to a point where taste and odor can be reduced to a minimum;

(3) Definite specifications for granular carbon should be established and research continued. Among the things to be considered in further study of the subject should be: the most feasible granular size, the hardness of the grain, the phenol number, the "wettability" of the grain, the depth of carbon versus the maximum rate of flow, and the relative re-activation value. The author wishes to express appreciation to the chemists of the Dow Chemical Company for their liberal cooperation in the accomplishment of the analytical work of the various experiments described in the paper and to the Dow Chemical Company and all other concerns who have been helpful in supplying the necessary carbon.

Discussion by *A. S. Behrman*.* It required a great deal of courage on Mr. Harrison's part in 1930 to make the first large municipal installation of granular activated carbon for the removal of tastes and odors. The results have amply justified Mr. Harrison's courage and foresight. The plant was completely successful from the very first, and has been operating successfully ever since under Mr. Harrison's competent direction.

Several features of the Bay City installation and of Mr. Harrison's paper deserve special comment in the light of developments that have transpired in the intervening years. Probably the most important of these are related to the question of the active life of the carbon and to the possibility of re-activating it economically.

Combined Powdered and Granular Carbon Treatment

One method of prolonging the active life of the granular carbon layers is the entirely commendable practice, employed in several large municipal plants confronted with highly aggravated taste and odor problems, of removing as much of the taste and odor as is practical with powdered carbon before passing the clarified water through a layer of granular carbon to complete the removal. This procedure is sound in practice as well as in theory. Powdered carbon costs less per pound than granular carbon, and is easy to apply in existing filter plants. There are aggravated taste and odor problems, however, which cannot be completely cleared up by powdered carbon unless employed in huge and prohibitively expensive dosages. In these cases, final treatment with granular carbon provides the logical and economical solution to the problem. It is not generally appreciated how radically different are the equilibrium conditions prevailing in the use of powdered and granular carbon, and how, therefore, granular carbon can be counted on to perform this final "cleaning-up" job more successfully and economically than powdered carbon. Another reason for the renewed interest in granular carbon for municipal installations is a growing appreciation of the characteristics of granular carbon plants that have made them standard equipment for industrial and institutional work: automatic and foolproof operation, complete taste and odor removal regardless of fluctuations in the raw water supply, and, normally, years of active life before replacement or re-activation becomes necessary.

* Chemical Director, International Filter Co., Chicago, Illinois.

Active Life as Measured by Phenol Adsorption Capacity

One apparent fact demonstrated very strikingly at Bay City was that the "phenol number" of granular carbon is not necessarily an accurate indication of its ability to remove tastes and odors. After the original granular Hydrodarco had been in service several years the "phenol number" dropped to a point where satisfactory taste and odor removal could no longer be expected, but in spite of this, the carbon continued to do an excellent job of taste and odor removal for another year or two.

The "phenol number" test or any other test for evaluating granular carbon in which the carbon is powdered before testing is open to the two principal objections, that: (1) equilibrium conditions in using granular and powdered carbon are radically different; and (2) test of a granular carbon in powdered form does not take into account the effect of the long-time service of granular carbon during which the effect of adsorption of other organic impurities as well as of the structure of the carbon surfaces may be to give the carbon particles a more or less impermeable coating which renders the interior of the particles relatively inaccessible and therefore inactive. As Mr. Baylis has pointed out on several occasions, there is as yet no very satisfactory test for granular carbon.

The method for evaluating granular carbon which Mr. Harrison has described in his paper overcomes some, but not all, of the objections of other procedures. It is used by International Filter Co. primarily as a control test for evaluating different samples of its own carbons. Like most control methods, it is largely an empirical (though reasonable) one. As Mr. Harrison has pointed out, it is not a test which exhausts the ultimate adsorption capacity of the carbon, any more than usual zeolite control tests completely exhaust a sample of zeolite. With all its limitations, however, the method is the most useful and generally satisfactory one that has been devised to date.

Reactivation of Granular Carbon

In 1930 the re-activation of spent granular carbon appeared to be an attractive possibility. Today, to those of us intimately associated with the manufacture and sale of the carbon, re-activation does not appear nearly so attractive. There are several reasons for this changed picture. One is that the price of granular carbon has been lowered so appreciably in the meantime that the differential between

the cost of new carbon and the cost of reactivation has shrunk very greatly. Several more purely technical considerations also deserve mention. The most generally effective method of re-activation is some sort of heat treatment, usually accompanied by controlled partial oxidation. This means that the carbon will ordinarily have to be shipped to the plant of the carbon manufacturer. Freight will have to be paid not only on the carbon, but also on an approximately equal weight of water with which the carbon is saturated. Add to this expense the cost of packaging the spent carbon, the loss of carbon in re-activation, and several other related debit items, and it becomes more apparent why the re-activation of what is now a low-priced chemical commodity has ceased to be economically attractive except in very special situations. It should also be remembered that the value of the spent carbon to the carbon manufacturer is determined by the cost of the low-priced raw material he regularly starts with in the preparation of new carbon. Any "trade-in" allowance in excess of this real value is obviously fictitious, and this real value is necessarily small. An additional and unlooked for disturbing factor that was discovered in one of the very few large-scale attempts that have been made to reactivate granular carbon from a water purification plant was the presence of enough gravel from the supporting medium to do serious damage to the mechanical equipment used in the re-activating process.

Space will not permit discussion of a number of other interesting points brought out in Mr. Harrison's paper or suggested by it. Suffice it to say, therefore, in conclusion, that the writer believes Mr. Harrison has made substantial contributions in this field by his work at Bay City and by his paper, both of which should help to clarify the proper place of granular activated carbon in the water purification picture.

Use of Activated Carbon in Purification Plants

By O. J. Ripple

IN PRESENTING the original paper, questions concerning the definition of activated carbon, a description of one process of manufacture, some examples of its use in water purification and a description of its use in the Denver filter plants were discussed. Since all but the last of these matters have already been treated in the JOURNAL and other water works publications (see reference list at end of paper), I shall confine my present discussion to a description of the use of activated carbon at the Moffat Filter Plant.

Powdered activated carbon was first used as an experiment in 1933 at the Marston Lake North Side Filter Plant, about five years after its first use by George R. Spaulding in New Milford, N. J., at the plant of the Hackensack Water Company. Table 1 shows the use of activated carbon at this plant.

The plant uses aeration to remove some of the tastes and odors from the lake water, and uses activated carbon intermittently as needed. At Denver the raw water very seldom exceeds a cold threshold odor of 3 or 4 except for a few days after the application of copper sulfate which is used once or twice a year to control micro-organisms. Consequently, as may be noted from Table 1, the Denver dosages of activated carbon are low, and carbons of a relatively low phenol removal value have been used as they have given satisfactory removal of the residual taste and odor at this plant where usually the effluent has a cold threshold odor of 1 or less.

The carbon for the plant is mixed with sodium aluminate and fed to the raw water in the mixing basin after aeration. Most of the carbon is carried over to the filters with the floc. Sufficient carbon settles to the bottom of the coagulation basin, however, to decrease

A paper presented on September 18, 1939, at the Rocky Mountain Section Meeting at Denver, by O. J. Ripple, Superintendent of Filtration for the Board of Water Commissioners, Denver.

materially the odor of the sludge as noted during basin cleaning operations. Short runs of activated carbon have also been used at the Marston Lake South Side Filter Plant from 1934 to date. The amount required at this plant is less than that necessary at the North Side Filter Plant, even without aeration, because the inlet to this plant is located much nearer to the inlet of Marston Lake than that of the North Side Filter Plant.

At the Moffat Filter Plant, which draws its raw water from Ralston Creek Reservoir, aeration is not employed and activated carbon, in varying amounts, is used continuously. There carbon is fed through a separate dry feed machine and is stored in a room separate from the coagulation chemicals. The carbon may be applied, wholly or in

TABLE 1

Use of Activated Carbon at the Marston Lake North Side Filter Plant

YEAR	DAYS USED	CONSUMPTION	RANGE IN DOSAGE
		lb.	*g. p. g.*
1933	3	425	.010–.010
1934	88	11,249	.006–.090
1935	137	21,383	.013–.062
1936	181	31,164	.010–.071
1937	178	29,938	.006–.087
1938	160	14,159	.004–.058
1939 (To Dec. 1)	254	43,961	.008–.087

part, to either the mixing basin or to the settled water conduit ahead of the filters.

During 1937, 2,435 lb. of activated carbon were used during the 34 days of treatment. The dosage ranged from .040 to 1.930 g.p.g. During 1938, 14,450 lb. of activated carbon were used in the 296 days treated. The dosage ranged from .007 to .480 g.p.g. During the first eleven months of 1939 there were used 116,497 lb. of activated carbon for the 334 days treated, the dosage ranging from .012 to .760 g.p.g.

Table 2 shows the use of activated carbon by months at this plant for 1939 and is included to demonstrate the high demand for carbon caused by an unusual odor in the raw water experienced from the first of February to the middle of May.

The unusual odor was probably caused by a deficiency of oxygen in the Ralston Creek Reservoir due to decaying vegetable matter

on its higher contours which were covered with water for the first time in the fall of 1938. These odors were quite difficult to remove and were the source of several complaints. The threshold odor on the cold raw water ranged from 3 to 8, musty and grassy in character, and from a trace to 3 T.O. with the same musty and grassy odor for the effluent water.

During the fall of 1937 a similar odor problem was experienced after the Ralston Creek Reservoir had been partially filled for the first time. This increase in odor was as pronounced as the one in 1939 but not as serious from an operational standpoint, since a very small

TABLE 2

Use of Activated Carbon at the Moffat Filter Plant

(By Months for 1939)

MONTH	DAYS USED	CONSUMPTION	RANGE IN DOSAGE
		lb.	*g. p. g.*
Jan.	31	910	.012–.067
Feb.	28	24,687	.180–.760
Mar.	31	26,471	.430–.700
Apr.	30	27,665	.240–.690
May	31	20,256	.017–.330
June	30	3,410	.015–.026
July	31	4,030	.017–.027
Aug.	31	3,428	.017–.025
Sept.	30	2,731	.019–.022
Oct.	31	1,448	.014–.030
Nov.	30	1,461	.023–.034

amount of water was used from this plant during the 1937 period of high odors.

To see if any saving could be effected by using carbons having a lower phenol value, three different brands of carbon were used during the period of high odors in 1939. Very little difference could be detected in plant scale operation tests as the cost per million gallons was about the same for the three brands used to reduce the original odor to the same residual odor.

This conclusion, that the cheaper grades of carbon proved as economical as more expensive grades, may not be true in other instances. The solution of each taste and odor removal problem must be worked out by trial at the plant in which the problem arises.

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Taste and Odor Control at Dallas

By L. C. Billings

THE production of water acceptable to a discriminating public may present many varied and complicated problems. Physical characteristics of a water are particularly subject to thorough public scrutiny. The important one seems to be that of odor and therefore taste. That "necessity is the mother of invention," is particularly applicable to the water processing industry. While the water production people do not in very many instances have the stimulus of competition, they do have to meet the more and more exacting specifications for water quality demanded by the public. The trend has been comparatively slow in development but is gradually overcoming the inertia of the older ideas of economy, permitting present operators of water plants to refine processes and produce a better physical and chemical product. Twenty-five years ago communities realized that their surface water supplies were subject to odor and taste conditions. Since the public was assured that the water was safe for drinking purposes the minor characteristics such as taste and odor were thought to be necessary. There are, today, many supplies in the same condition awaiting public demand for a "clean up."

The subject of taste and odor control is so broad in its scope that it is an impossible task to discuss the many varieties of conditions found over the country. This paper will concern itself solely with the author's recent experience at Dallas, Texas. Conditions there are fairly representative of those in other parts of the Southwest.

The raw water supply of Dallas consists of an impounded lake discharging through adjustable gates into an open channel which is a natural stream bed. The capacity of this lake was originally 63

A paper presented on September 18, 1939, at the Rocky Mountain Section Meeting at Denver, by L. C. Billings, Superintendent and Chief Chemist, Water Purification Plant, Dallas, Texas.

billion gallons, but silting, over a ten-year period, has reduced this capacity. Water is taken from the bottom of the lake through a fixed outlet. The lake receives its supply from fall and spring rains. For a greater portion of the year there is no inflow to the lake except that of a small stream carrying an inadequately prepared sewage plant effluent. This inflow amounts to approximately 1 m.g.d. of water carrying 900 p.p.m. solids consisting mostly of the soluble solids of sodium carbonates, bicarbonates, sulfates and chlorides. The water at the lake outlet has a dry weather total solids content of approximately 275 p.p.m. consisting mostly of calcium-bicarbonates and sulfates and chlorides and 0.6 p.p.m. nitrate (NO_3). Turbidity varies from 25 to 200. The water is free from color. Just what influence the high solids and organic content of the inflow water of the small stream has on the lake water has not been definitely determined.

Through the fixed outlet at the bottom of the lake the water flows into an open channel which meanders approximately 60 miles to the plant intake. There are flashy contributing streams between intake and lake which add much to the coagulating, softening and odor load problems at the purification plant. On the stream there are two dams located some distance apart. Each of these impounds several hundred million gallons. Except at times of rainfall the volume of the main stream is usually small (93 m.g.d. takes care of maximum plant and stream demands in dry weather time) and of low velocity through many shifting timber drifts. The stream banks are fringed by extensive forest growth from which trees, dead wood, etc. are dislodged from time to time by flood to make up the timber drifts. Much work has been done to remove them, but each river rise brings another series. On settling back with fall of water, they form excellent collectors for all floating material, offering abundant lodgement and consequent growth of water plant life.

The treatment plant is the conventional softening, coagulation, filtration and chlorination plant. Water characteristic and chemical quantity averages are shown in Tables 1 and 2. Softening consists of lime treatment to the extent that the finished water is left saturated or super-saturated with calcium carbonate. It is aimed to alternate the two conditions approximately over equal periods of time. There is no recarbonation and it would be useful only for comparatively short periods. CaO (96 per cent) is proportioned dry and slaked continuously. Primary coagulation consists of chlorinated-copperas applied simultaneously with the lime. The ferric salts, ferric sulfate

and ferric chloride, are considerably more effective than the ferrous salt. Chlorine is introduced into the ferrous iron solution immediately before addition to the water. Secondary coagulation is then accomplished by addition of aluminum sulfate shortly before sand filtration. Dry feeders proportion the coagulants.

All chlorination takes place after filtration although there is additional provision for pre-chlorination in settled water. Ammonia is added to the settled water in the form of ammonium sulfate. The

TABLE 1

Water Characteristics—1938

	RAW WATER	FILTERED WATER
Total Alkalinity	123 p.p.m.	34 p.p.m.
Non-carbonate Hardness	22 p.p.m.	32 p.p.m.
Total Hardness	145 p.p.m.	66 p.p.m.
Turbidity	287 p.p.m.	0.1 p.p.m.
Color	None	None
Odor, T.O., 1938	63	10.4
Odor, T.O., 1939 (8 mo.)	120	9.0

TABLE 2

Chemical Dosage Annual Report—1937–38

Lime	4.9 g.p.g.
$FeSo_4$	0.69 g.p.g.
Cl_2 for $FeSo_4$	1.04 g.p.g.
Alum, Secondary	.47 g.p.g.
Chlorine (disinfectant)	.85 p.p.m.
Ammonia	.29 p.p.m.
Carbon	10.4 p.p.m.
Carbon, 1939 (8 mo.)	22.0 p.p.m.

usual advantages of chloramination are realized. Chlorine is purchased in ton containers.

The principal problem encountered in operation is control of tastes and odors. This is accomplished by adsorption with carbon and adjustment of the chlorine-ammonia ratio.

Provision is made for feeding carbon at three different points. The major dose is applied in the raw-water conduit leading from the river channel to the pumping station, being a split dose applied near river intake (50 per cent) and at the pump suctions (35 per cent). The smallest dose is applied between the primary and secondary settling basins (15 per cent).

The primary odors in the Dallas raw water supply develop in the impounded lake water. The lake was completed in 1927. It has been in use as a water supply since 1930. There are many shallow areas, its average depth being approximately 20 ft. at summer elevation. The first six years of use presented no particular odor problems. The water received at the purification plant did carry odors frequently, due to quick runoffs on streams entering the river channel between the lake and intake, but these were of such character that they were handled easily by coagulation without leaving too much residual odor in the finished water. About three years ago attention was first focused on the lake odor condition. It is suspected that had the odors been measured through the years a cumulative condition would have been noticed. Such has been the experience during the last three years. While the odors rise and fall through the seasons, new highs are noticed for each succeeding year.

Careful study of the lake flora during the past two years has indicated that contrary to the popular thought the odors have not been caused by any specific organism known to produce odors. High concentrations of organic matter are present. Bottom muds are odoriferous. Strong odors come in from the creek area carrying the sewage plant effluent. Diatoms and chlorophyceae bloom and die periodically. The sum total of the characteristic odor seems to be well expressed by the citizens' phrase "branch water taste and odor" which would commonly be expected to come from stagnated water which has from time to time become subjected to various biological processes. The laboratory designation of these odors is: musty, grassy and earthy.

Late last year the City engaged the services of biologists to make intensive studies on the conditions prevailing at the lake, the dominant purpose being to find a correlation between existing odors and biological life which would result in a suggestion for remedial measures. This work did not start until May 1, 1939, so the time period has not been of sufficient length to complete studies and apply any methods of treating the lake biologically. Consequently there has been no relationship established between odor production and the existence of aquatic life. A large amount of information is being collected and it is expected that at the end of another year more progress can be reported.

An idea has been suggested which is thought might lead to a solution of the odor problem. By proper balancing of fish life, mussels, etc., with plant life there may be reached a balance whereby organic

matter will not exist in sufficient quantities to produce the water odors. We know that fish life can be maintained by supplying the proper diet in controlled quantities, but it is not certain that such treatment will control the odors in the water. The experiment will be watched with interest. This work involves the methods of the limnologist consisting of the following regular program of tests:

(1) Temperatures and turbidities.
(2) Alkalinity and dissolved oxygen.
(3) High speed centrifuging of samples for residue weight.
(4) Examination of water for:

Ammonia	Fats
Nitrites	Silica
Nitrates	Phosphates
Total organic nitrogen	Chlorides
Organic nitrogen as protein	Dried weights of residue

(5) Making organism counts from the plankton net catch and concentration of small samples with Sedgewick-Rafter filter. Organisms are identified.
(6) Studies on water at different depths to detect any stratified conditions.
(7) Nitrogen studies on lake bottom muds.

The water purification laboratory has maintained a systematic routine of sampling of lake waters and river channel consisting of the following items:

(1) Temperatures and turbidities.
(2) Plankton counts and identification by Sedgewick-Rafter method.
(3) Determination of threshold odors of all samples.
(4) Alkalinities and dissolved oxygen.
(5) Daily threshold odor determination from intake through the water purification plant to finished water.

In all studies connected with a program of this kind the threshold odor test becomes the yard stick for measuring results. Likewise in controlling the plant process the use of this test is a necessity. At the Dallas Water Purification Plant laboratory one man is thoroughly trained and practiced to expertness. Should he be temporarily incapacitated the tests can be carried on by others similarly trained but not so practiced. This man spends 50 per cent of his time in making from 90 to 100 threshold tests per week.

The program at the lake was the first line of defense in the attack

on odors. It is hoped that the planting and propagation of the proper varieties of fish, mussels and plants will effect a decrease in odors.

The second line of defense was the execution of a copper sulfating program three times during the growing season, March, May and June. This was designed to keep down the growth of organisms that would cause odors by living process or from decomposition. The flora was greatly reduced and some varieties were completely eliminated, yet the odor concentration remained high and continued to increase normally with the rising temperature and increasing hours of sunlight. In general an increased growth or bloom of organisms

TABLE 3

Threshold Odors at the Treatment Plant

	JULY, 1939				AUGUST, 1939			
	Av.	Max.	Min.	Med.	Av.	Max.	Min.	Med.
Lake	123	185	70	125	109	160	20	115
River	124	175	90	135	160	190	125	160
Filtered Water	10	16	6	10	13	26	6	14
Carbon Used p.p.m.	31	48	23		42.4	52.5	35.9	

TABLE 4

Threshold Odor—Sept. 13, 1939; Degree of Removal Through the Plant

	T.O.
River	100
Between Aerator and Mixing Channel	60
Primary Settling Basin	45
Secondary Settling Basin	19
Top of Filters	19
Filter Effluent	6
Tap	4

(diatoms mostly) seemed to be followed after a short period of several days by an increase in odor intensities, indicating odor production from the decomposition of the common types of organisms. Accurate correlation between the number of organisms and odor, however, does not seem to have been established.

Some copper sulfate was applied to shore line and shallow areas to kill certain growths. Application was made by motor boat and burlap solution sacks, and some shore line treatment by scattering the crystals. During greater part of the summer, 0.25 p.p.m. $CuSO_4$ was added continuously to the lake outlet. Certain areas on the river channel were coppered where growths of *Oscillaria* showed

TABLE 5

Summary of Odor Removal; Threshold Odor Number at 70°C.—1938-39

1938-39	LAKE DALLAS WATER						FILTER PLANT INTAKE WATER						FILTERED WATER						CHLORINATED FILTERED WATER					
			Variation in Number						Variation in Number						Variation in Number						Variation in Number			
	Average	Median	No. of Tests	10-50	51-100	>100	Average	Median	No. of Tests	10-50	51-100	>100	Average	Median	No. of Tests	0-5	6-10	>10	Average	Median	No. of Tests	0-5	6-10	>10
October	72	80	14	3	11		78	80	30	1	26	3	3	3	30	25	5		4	4	30	24	6	
November	80	80	4		4		83	80	27		25	2	4	4	28	27	1		4	5	28	25	3	
December	88	85	10		10		87	90	29		29		9	9	27	3	21	3	9	10	29	1	19	9
January	130	125	7			7	137	140	27		1	26	14	14	27		5	22	12	12	27		12	15
February	149	150	10		10		162	165	26			26	14	14	27		3	24	10	10	27		17	10
March	130	135	19	1	4	14	132	135	28	2	3	23	11	12	28	3	8	17	8	8	28	6	17	5
April	31	30	15	15			82	80	28	5	16	7	7	6	29	10	16	3	6	5	29	17	12	
May	40	35	10	9	1		69	65	27	4	22	1	7	6	30	9	17	4	7	6	29	10	15	4
June	63	70	15	5	10		97	85	29		22	7	10	10	29		15	14	9	8	29	1	23	5
July	123	125	14		5	9	124	135	30		9	21	11	10	30		17	13	8	8	30	3	20	7
August	109	160	12	2	3	7	160	160	30			30	16	16	30		3	27	13	14	30		9	21
September	103	110	10		5	5	119	110	28		13	15	11	10	28	4	12	12	8	8	28	7	12	9
Total			140	35	63	42			339	12	166	161			343	81	123	139			344	94	165	85
Average	93	98					111	110					10	10					8	8				
% Tests			100	25	45	30			100	3.5	48.9	47.6			100	23.6	35.9	40.5			100	27.3	47.9	24.8

considerable activity. This was done in July and August. The net result of the coppering was the checking of organism growth but there was no diminution in the odors, although it cannot be estimated what the odors might have been if no copper sulfate had been added. It is felt from last year's experience that more timely application might have produced better results.

The third line of defense, the water purification plant treatment, had to take the full burden of odor removal. With an increased odor load over that of other years the plant turned out the best effluent of any previous year over the same period of time. This was accomplished by adsorption of the odor with carbon and proper adjustment of chlorine and ammonia ratios. Total carbon dosages reached as high as 50 p.p.m. Post-chlorine doses were reduced and the chlorine-ammonia ratio was maintained at 3 to 1. Table 3 indicates the extent of odor loading on treatment plant.

The use of the threshold odor test in plant control work takes the guesswork out of plant operation. The method, used only two or three years ago, which consisted of naming the odor by initial with a sub-figure to denote intensity was of no value whatsoever in plant control work.

Particularly valuable is a frequent carbon-demand test as determined with the threshold odor test. In such a test various amounts of carbon are added to the raw water and the amount of carbon required to reduce the threshold odor to a certain value is determined. This often serves as a good guide in setting the feed of carbon. At Dallas it was found that by adjusting the carbon feed to 75 per cent of the carbon demand, the threshold value was obtained.

Another scheme found to be exceedingly useful was that of maintaining a certain residual odor at some given point in order to insure a satisfactory result in the effluent. In the Dallas system it was found proper to maintain a T.O. value of 50 to 60 in the primary settling basin prior to the addition of the third dose of carbon. This plan provided early adjustment of the feed of carbon.

In Table 4 the odor values in both raw and finished water are summarized monthly for the city fiscal year 1938–39.

Table 5 indicates a typical degree of odor removal through the plant. It is representative of average results.

Methods of control made possible by use of the threshold odor test not only provide an intelligent means of insuring the removal of objectionable odors but make economical operation possible by saving material when treating variable odor intensities.

Handling and Feeding Activated Carbon at Detroit

By Newton Powers

FOLLOWING the introduction of activated carbon into water purification, the past decade has witnessed what amounts to an almost general acceptance of the material by a profession growing rapidly taste and odor conscious. During this relatively short period, the quality of water carbons has been constantly improved by manufacturing research in response to operators' demands, but the difficulties of handling and feeding the material have been met and solved almost entirely by the men in the field. While some of these problems may be common to the field using carbon, there are some plants that have problems peculiar to themselves. It is the purpose of this paper to describe the difficulties encountered and the methods now used successfully in the handling and feeding of carbon at the Water Works Park Filtration Plant in Detroit.

Powdered activated carbon was first used at this plant on January 31, 1936, by dumping the material straight from the bags into the filters. This was purely an emergency treatment and was obviously unsatisfactory: first, because the control was inaccurate; second, because it was difficult to wet the material thoroughly by this method; and third, the plant quickly presented a dirty appearance.

Feeding the carbon by means of one of the standard volumetric dry feed machines was then tried. Inaccurate delivery resulted, and at times the carbon refused to flow from the hopper to the feeder as a result of either arching or funneling. It was quickly realized that to feed the material successfully it would be necessary to keep it in active movement by mechanical vibration. For this purpose a dry feed machine of the electrical vibrating type was secured on approval. The operation of this machine demonstrated that it would

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be necessary to install a dry feeder of the gravimetric type, so a fully automatic gravimetric vibrator-feeder was purchased. This machine performed very satisfactorily, but still left several other problems to be solved:

1. After being delivered from the dry feeder in the proper amount, it still remained necessary to convey the carbon from the machine to one or more points of application, and to ensure thorough wetting and dispersion.

2. There existed a tendency for the carbon to funnel or arch in the hopper.

3. For the sake of cleanliness, the entire system had to be made as dust-proof as possible.

4. Owing to an unexplained outbreak of fire which occurred in the carbon hopper on June 29, 1937, this hazard had to be guarded against.

In this paper no detailed explanation of the many attempts to overcome these difficulties will be attempted; however, a brief description of the present setup which to date has given satisfactory operation is in order.

Each bag of carbon is opened and inverted into a rectangular receptacle located above and forming part of the hopper covering. This receptacle is tapered and is so designed as to cause the bag to fit snugly into place without allowing it to fall into the hopper. The carbon discharges freely and quickly from the bag with practically no dust. This receptacle is also supplied with a $\frac{1}{2}$-inch mesh screen to prevent the entry into the hopper of paper or any other foreign material.

The hopper itself is constructed of $\frac{1}{8}$-inch steel plate, riveted and welded into the shape of an inverted pyramid, 11 ft. square at the top, 9 ft. deep, with a 12-inch opening at the bottom. The cover of the hopper, which is also of $\frac{1}{8}$-inch steel plate, is felted at the edges and bolted to the structural framework of the hopper. This cover is easily removed.

The displacement of dust laden air from the hopper, when filling from bags, is through an 8-inch square-section steel ventilating duct, which discharges from the top of the hopper to a point outside the building. This ventilating duct is constructed with an elbow to prevent the entry of rain or snow. Since the duct would form a natural outlet for heated gases should a fire develop in the hopper, an adjustable stack thermostat is located within it. When tripped,

this thermostat sounds an electrical alarm on the operating floor of the filter building. Sounding of this alarm requires the operator on duty to make an immediate inspection of the hopper interior through an observation door which is fitted with a portable dust proof lamp for that purpose. If the inspection reveals that a fire has started, a conveniently located valve is opened, which, through a suitable system of piping and outlets, allows a very finely divided spray of water to descend on the carbon. This spray is sufficient to smother the fire without allowing the carbon to be wetted to an extent where a slurry would be formed. One firm which manufactures carbon dioxide fire extinguishing equipment has recently adapted its apparatus to use in carbon hoppers.

The steel hopper, with a capacity of $8\frac{1}{4}$ tons of carbon, was so constructed that it would fit into an existing concrete hopper, separated from it by 2x2-inch wood strips. Two opposite sides of the steel hopper are each furnished with a standard electrical vibrator, each being located about 3 ft. from the bottom at points specially reinforced to receive the vibrations. These vibrators effectively prevent the carbon from arching and funneling. The carbon leaves the bottom of the hopper and passes to the dry feed machine through a steel tube 12 in. in diameter and approximately 6 ft. in length. The discharge tube is also supplied with a vibrator.

Earlier experience had shown that if the carbon flow was temporarily obstructed immediately above the dry feed machine, and the obstruction removed after the machine had emptied itself, a carbon flow ensued of such velocity that it would pour right through the machine and out of every possible opening. When this occurs, the carbon flows with all the characteristics of a fluid, a large mound of carbon forming quickly all around the machine. This difficulty indicated the advisability of having some means of shutting off the carbon flow. A quick closing gate valve was constructed and installed in the 12-inch hopper discharge tube at a convenient height immediately above the dry feed machine. The gate was cut out of $\frac{1}{8}$-inch sheet steel and was retained within guides fabricated of the same material. The valve is opened or closed by pulling or pushing on a handle that is an extension of the gate proper. The connections between the handle and the gate pass through felt lined slots which serve the same purpose as the packing gland on a hydraulic valve.

The carbon passes through the gate directly into the vibrating hopper of the dry feed machine, which is fully enclosed to minimize

the escape of carbon dust. A small hopper was constructed and attached to the dry feeder to receive the carbon as it is freely discharged from the weighing belt. This hopper is fitted with a felt lined door to provide a means of securing a sample for weight checking. The hopper consists of a rectangular section reaching to a point slightly below the sampling door, and from there it tapers as an inverted pyramid to its connection with a 2-inch pipe. Suitable supports for the sampling pan are provided, and immediately below these supports, a piece of $\frac{1}{2}$-inch pipe extends across the hopper. Water supplied through this pipe passes through two rows of small holes, spraying the sides of the hopper and washing off all carbon which tends to adhere.

The 2-inch pipe at the bottom of the hopper is the suction end of a hydraulic ejector operating on about 60 lb. water pressure. This ejector creates a partial vacuum within the hopper, effectively disposing of all the carbon as rapidly as it is discharged from the machine. The ejector also serves the purpose of wetting down the carbon thoroughly, forming a very thin slurry which is conveyed by pipe line and valves to the various points of application.

To prevent the escape of carbon dust to other parts of the plant, the dry feed machine is housed in a room built for that purpose; and on the walls of the room are located all switches and controls for operating both the dry feeder and the hopper vibrators.

Sewer Rental Financing

By William Storrie

THE search by municipal authorities for additional sources of revenue has resulted in the consideration of special charges on the right to use the sewerage system. These "sewer rentals" or "sewer service charges" are a subject of considerable interest to water works authorities due to the prevailing tendency that such rentals should, in part at least, be collected as a revenue through added charges on the water works bill. In Canada there seems to be no legislative authority to permit the collection of operating and maintenance charges either through the water works bill, depending on the volume of water supplied, or on a frontage basis. The costs have invariably been a charge on the mill rate.

All municipalities have property which is exempt from certain general taxation. With few exceptions water supplied to such exempt property is paid for by a direct charge depending primarily on the quantity used. In most cases a large percentage of this water finds its way into the sewer system and may ultimately have to be treated at a sewage plant. The exempt properties, however, contribute nothing toward the operating and maintenance costs of the sewerage system and in addition make no contribution toward the capital or operating and maintenance costs of the sewage treatment plant. In Ontario the cost of installing a system of sewers is usually paid for under the terms of the Local Improvement Act and in certain cases such exempt property has to pay its share on the foot-frontage basis, but no charge under the Local Improvement Act can be made against property owned by the Federal or Provincial Governments.

A paper presented on March 28, 1940, at the Canadian Section Meeting at London, Ontario, by William Storrie, Gore & Storrie, Consulting Engineers, Toronto, Ontario.

Under Section 405, subsection 53, of the Ontario Municipal Act appears the following statement:

"For charging all persons who own or occupy land drained, or which by by-law of the council is required to be drained, into a common sewer, a reasonable rent for the use of it; for regulating the time and manner in which the rent is to be paid; for providing for the payment of a commutation of such rent or charging a gross sum in lieu of rent and for the payment of such commutation or gross sum either in cash or by instalments with interest.

(a) This paragraph shall not apply to a sewer constructed as a local improvement.

(b) All sewer rents shall form a lien and charge upon the real estate upon or in respect of which the same have been assessed and rated or charged and shall be collected in the same manner and with the like remedies as ordinary taxes on real estate are collected under the provisions of The Assessment Act."

This would appear to be an alternative method for collecting the cost of installing a sewer to one constructed under the terms of the Local Improvement Act, which enables the cost of installing a sewer to be recovered over a period of years as an annual charge on the frontage of the property served. While this section of the Municipal Act affords an alternative means of taxing the property for use of the sewerage system, it cannot be construed as a means of taxation for the use of a sewage treatment plant. The cost of maintenance and operation of a sewer cannot be recovered under the terms of the Local Improvement Act. It is also doubtful if such operation and maintenance charges can be recovered under Section 405, subsection 53, of the Municipal Act. This section enables the property owner to pay outright a lump sum as a rental charge for the use of the sewer and a reasonable interpretation is that such an initial charge can be based only on the capital outlay required to construct the sewer. As far as is known little advantage has been taken of this section of the Municipal Act to recover the cost of installing a sewerage system although it appears that property exempt from general taxation could be charged under this section.

Under Section 414, subsection 2, of the Municipal Act a municipality is given power to pass the necessary by-law permitting the cost of the collection of garbage and the cost of disposal of same to be charged against all properties exempt from general taxation. This section of the Act reads as follows:

"For the collection, removal and disposal by the corporation of garbage or of garbage and other refuse or of ashes, garbage and other refuse throughout the whole municipality or in defined areas of it at the expense of the owners and occupants of the land therein, and for imposing upon such land according to its assessed value a special rate to defray the expense of such collection, removal and disposal.

(a) Subject to clause (c) no land shall be exempt from the special rate, anything in any general or special Act or in any by-law to the contrary notwithstanding.

(b) The special rate may be collected or recovered in the manner provided by section 524.

(c) In the case of a place of worship the council may by by-law provide that the special rate shall be imposed upon the land according to its assessed value exclusive of the assessed value of the buildings."

It is to be noted from the above that the cost is recovered by a special rate on the assessed value of the land and buildings thereon with the sole exception that the special rate on places of worship shall be imposed only on the assessed value of the land.

Since 1915 the City of Kingston has been operating under this section of the Act. The City by-law states there shall be no exemptions. There have been instances, however, where certain properties owned and occupied by federal authorities have refused payment of this rate. In such cases the charges have been written off as bad debts.

In the Kingston case it is interesting to note that the assessment in 1939, for general purposes, was $19,410,689 and for garbage collection purposes was $24,384,185. The difference between the assessment for general purposes and that for garbage collection is made up of those properties that are exempt from general taxation such as hospitals, schools, public utilities, universities, churches, etc. The municipality includes in the sum required to be levied the cost of the removal and disposal of the garbage, the annual charges on capital expenditure, and such other capital expenses as are paid directly out of the rate imposed. In 1938, for instance, a new incinerator unit, two new trucks and physical changes made in the garbage disposal plant were items of capital expenditures which were pro-rated over a 5-year period. The rate imposed in Kingston is strictly on the assessed value of the property and not on a rate per foot frontage.

The legislation covering the raising of revenue for garbage collection and disposal appears clear in definition and if such is appli-

cable to the operation and maintenance costs of a garbage system it would appear reasonable that an assessment along similar lines should be permissible for the operation and maintenance costs of a system of sewers and sewage treatment plant. Furthermore the annual fixed charges on the capital investment might reasonably be secured from such a special charge.

To make a study of what has been accomplished on the problem of sewer rentals, one must turn to the United States where legislation permitting such charges has been enacted in 35 of the 48 states. For detailed study of the subject, reference should be made to Bulletin No. 7 on sewer rentals, published by the American Public Works Association. This survey covers the administrative practices and experiences of 104 cities situated in 24 states and deals with such matters as rate structures, special rate problems, billing practices, collection practices and disposition of revenues. Upwards of 600 municipalities in the United States are using this plan of collecting revenue for sewage disposal purposes.

The problem should be approached from the viewpoint that the charging of sewer rentals is primarily a means of raising municipal revenue. The proper distribution of the costs of municipal government among the various members of the community is an important problem in the field of municipal finance. Sewer rental practice shows wide variations in the extent to which revenues from that source are relied upon to meet capital, operating and maintenance costs of sewage disposal systems. In this connection one cannot do better than quote from the above cited bulletin as follows:

"In some cities service charges are used to finance the construction of new sewer systems or new treatment plants, in others to pay the debts against existing sewerage works, and in still others to pay the current operating and maintenance costs of the sewers or treatment plant or both. Earmarking of the revenues is by no means universal, however, and many communities make no effort to allocate the receipts from sewer rentals to any specific elements of sewerage cost."

There are a number of important differences between a sewer service and such other public utilities as are common to most municipalities. To connect to the sewer system is practically a compulsory matter and in this respect is different from the gas or electric utilities. Should some of the other utility rates be unduly increased the use of such services will decrease but the use of a sewer system is more

or less independent of the level of the rates. Again the individual benefit derived from community-wide sewer service in relation to the public benefit is very much greater than from most utilities. From the viewpoint of endangering the health of the community at large the severance of the sewer connection as a means of enforcing collection of the sewer charges would be considered inadvisable. In most municipalities the treatment of sewage is desirable and yet in many cases the municipality does not derive any direct benefit from such treatment. Often, instead, it is some other municipality that derives the real benefit.

Bases for Sewer Rental

Establishing a schedule of sewer rental charges is a complicated matter. In the first place the portion of total cost which can properly be borne by the municipality as a whole must be determined, and for the remainder a reasonably accurate measure on which to charge for the degree of individual benefit received must be ascertained. A study of the United States situation indicates six different methods in use in fixing sewer rental charges: (1) by a uniform charge, (2) by number of sewer connections, (3) by type of property, (4) by number of plumbing fixtures, (5) by water consumption, and (6) by metered sewage. Many difficulties arise in some of these methods. A uniform charge is unfair to the smaller consumers. Charges based on the plumbing fixtures are difficult to administer and may tend to undercharge some of the larger consumers. Metered water is the closest approximation to a measure of the use of the sewer system. It is dependent of course upon the complete metering of the water system, and modifications have to be taken into account for private water supplies and such industries as use large quantities of water which are not discharged into the sewer system.

Source of Data

Sewer rentals have been adopted on a large scale in the states of Ohio, New Jersey and Texas. In the early stages the sewer rental plan was adopted mostly in smaller communities. The method is, however, spreading and several cities of over 500,000 population have either adopted this means of financing or have it under consideration. The largest municipalities have not, however, seen fit to adopt any such plan as yet. Table 1 shows the various sizes of the municipalities reporting use of some sewer rental system.

There is a wide variation in the officials on whom the responsibility is placed for the management of the sewer system. In most cases responsibility is placed on either the superintendent of sewers, superintendent of water and sewers, superintendent of water, or the city engineer; but in one case the management is in the hands of the chief of police; in another, in the health officer; and, in a third, under a section known as the "Department of Water—New and Used." The billing and collecting of the sewer rental charges generally is done by the personnel and with the facilities that already exist for the collection of taxes, licenses and water bills.

Of 90 cities reporting, 63 had a separate sewer system, 24 a combined system and 3 a combination of the separate and combined systems. In 79 of these municipalities, sewage was treated and in 11

TABLE 1

Spread of Size of 104 Cities Reporting Sewer Rental Systems

POPULATION GROUP	NO. OF MUNICIPALITIES REPORTING
Less than 5,000	38
5,000 to 10,000	19
10,000 to 25,000	28
25,000 to 50,000	8
50,000 to 100,000	5
Over 100,000	6
Total	104

no sewage treatment plant was in use. In answer to another question, of 99 cities reporting, 13 had no sewage treatment plant, 25 had a partial form of treatment and 61 complete treatment.

Various Rate Structures

It has already been pointed out that sewer rental rate structures are based on six different classifications, the water consumption and plumbing fixture plans being most widely used. The following information is of interest in that it gives details of the different rate structures set up under the various classifications.

In all, 8 municipalities, out of 100 reporting, based their rate structure on a uniform rate. It is the simplest of all rate structure bases and is easiest to establish. Its purpose is to spread the cost uniformly among all users, but the rates do not represent a fair

payment for the actual use of the sewerage system. Inequitable charges arise from such discrepancies in use as exist between a commercial laundry and a private residence. Under this method, however, the same rental charge applies in each case. This method is restricted to a few small municipalities and aside from its simplicity there is little to recommend it. The rates charged in the 8 municipalities vary from $3 to $10 per annum.

The method based on the number of sewer connections from each property is somewhat similar to the uniform rate basis. It has an advantage in that a property may have two sewer connections presumably because of a larger volume of sewage and thus an additional charge for the extra connection is made. It does not, however, provide any real measure of the actual use of the sewer facilities. Its adoption has been mostly confined to small communities where important differences in the properties do not exist to any great extent. Most of the municipalities using it have a population of less than 5,000. Generally the rates for each connection vary from $1.50 to $26.64 a year. In one case a 4- or 6-inch sewer connection is charged $13.32 a year while an 8-inch connection is $26.64 a year. In another case $5.00 annually is charged for a two-family building even where there is only one sewer connection whereas the regular rate per sewer connection is $3.00 a year. In other cases special rates for industries have been established. A total of 12 municipalities use the sewer connection basis of payment.

Nine of the municipalities reporting use type of property as a basis for sewer rental. Differentiation is usually made between sizes of residences, and type and size of commercial or industrial plants. The classification of properties can be quite limited or very comprehensive. Some cities have but 7 classifications where others have as many as 50. Obviously in the more detailed classification many of the inequalities that otherwise would exist are eliminated. Some residential charges are based on the number of rooms in a house but the general policy is based on the number of families that occupy the house. Under this schedule of rates, based solely on the type of property, many inequalities are bound to exist. In an effort to overcome such inequalities some municipalities have introduced additional charges on the basis of the number of baths and the number and kind of plumbing fixtures. The range in rates charged in certain municipalities for some typical property classifications is shown in Table 2.

Thirty-three municipalities use the plumbing-fixture basis. It appears to find favor in communities where the water works system is privately owned, where water meters are not installed or where it may be desirable to favor to some extent the poorer class of users. The system measures roughly the presumptive use of water and therefore is a general guide to the use of the sewers. For various reasons the rate schedule is somewhat complicated but once the number and type of plumbing fixtures have been classified for each property and the rates established administration is simple. The range in charges reported for the more common type of plumbing fixtures is shown in Table 3. Objection is sometimes taken to the fixture method as being an unfair basis of measurement but it is just as fair for sewage as it is for water.

TABLE 2

Range in Sewer Rental Rates Charged By Certain Municipalities on Typical Property Classifications

CLASS OF PROPERTY	MINIMUM ANNUAL CHARGE	MAXIMUM ANNUAL CHARGE
Residence	$1.80	$12.00
Stores	5.00	18.00
Schools	10.00	30.00
Apartment Buildings	2.50	19.80
Hotels	2.00	60.00
Public Garages	6.00	30.00
Railway Depots	3.00	12.00

Thirty-seven of the municipalities reporting have adopted the metered-water method for the rate basis. Of all the methods adopted this represents the most accurate measure of the relative use made of the sewerage system and, in general, results in the most equitable distribution of charges. The metered-water basis is a good measure of the service charges for maintenance and operation of sanitary sewers and treatment works, although special circumstances must be given consideration. Certain inaccuracies exist in that the water used may not all be discharged into the sewer system. On the other hand it is faulty in not taking into account sewerage facilities offered to vacant property and to large commercial and industrial establishments that use very little water. Such properties do not therefore contribute in relation to the total benefits enjoyed and an adjustment has to be made.

The cities charging sewer rentals on a metered-water basis usually specify a minimum charge. Such a charge varies all the way from $0.80 to $9.00 annually for residential and commercial properties. Sometimes the minimum charge is based on the size of the water meter which is similar to the readiness-to-serve charge commonly used in water rate structures to cover expenses that are fixed and not dependent on the amount of water consumption.

There is a rather wide range in the charges made, varying all the way from two-thirds of a cent to 60 cents per 1,000 U.S. gallons of water used. A study of the rate structures based on water consumption shows little evidence of scientific determinations. The American Public Works Association bulletin cited above states: "There appears to have been an effort made to raise a definite amount of revenue in the least painful manner, rather than to fix the charges in true relation to the cost of providing the service."

TABLE 3

Range of Sewer Rental Charges by Plumbing Fixtures

TYPE OF FIXTURE	FIRST FIXTURE		EACH ADDITIONAL FIXTURE	
	Minimum Annual Charge	Maximum Annual Charge	Minimum Annual Charge	Maximum Annual Charge
Toilet	$.60	$7.22	$.40	$3.61
Toilet in Commercial Property	.30	15.00	.20	6.00
Sink	.36	7.22	.36	3.61
Sink in Commercial Property	.36	15.00	.36	12.00
Lavatory	.25	1.50	.25	1.50
Lavatory in Commercial Property	.36	5.00	.36	5.00
Bathtub	.36	7.22	.20	3.61
Hotel Bathtubs	.20	7.22	.10	3.61
Shower	.36	7.22	.36	3.61
Urinal	1.00	3.61	1.00	3.61
Urinal in Commercial Property	1.00	5.00	1.00	5.00
Public Garage Wash Rack	1.80	21.66	1.80	21.66
Laundry Tubs	.36	7.22	.36	3.61

The quantity of sewage discharged is probably the most equitable measure of the relative use of the sewerage system. A meter that will accurately measure this quantity has not yet been developed. Fairly accurate quantities, however, can be ascertained by the available measuring devices. Only one city, Phoenix, Arizona, uses

this method and there it applies only to properties situated outside the city limits which have access to the city sewerage system. A rate of 70 cents per 1,000 U. S. gallons is charged. The cost of installing a meter system together with the reading and billing of the quantity of sewage discharged would add considerably to the cost so that for the present at least the use of sewage meters is likely to be confined to properties contributing large volumes of sewage or to certain special cases.

Certain combinations of these rate structures have been adopted. In two municipalities a single service charge is levied for both the sewerage and water services. Here again caution must be urged. The chief advantage of the method is that it simplifies the accounting system. Obviously certain adjustments would have to be made in the combined rate structure to provide for water used but not discharged into the sewer and for water obtained from private sources.

A method that might quite well be adopted is known as a fixed percentage of the water bill. Under such a plan the billing is simpler and less costly than where a separate rate structure is adopted. The method can be used for all properties whether metered or unmetered. The fixed percentage applied against water bills varies widely, from 10 per cent to 100 per cent with a normal range from 20 per cent to 50 per cent. Such a percentage means very little unless the basis of the water rate structure is known.

Other difficulties arise in establishing a rate structure that is equitable where wide variations exist in the strength of the sewage. Generally, exceptionally strong sewage costs more to handle in a treatment plant than ordinary domestic sewage. On the other hand large volumes of clear water discharged into the sewer system can be treated at less expense than ordinary sewage.

Experience in Buffalo, N. Y.

The Buffalo Sewer Authority has set up means of deriving revenue for the operation, maintenance and fixed charges of the sewage disposal system based on sewer rents. The experience indicates this method has met with general acceptance. The schedule of sewer rents adopted divides the obtaining of revenue to meet the first year's budget requirements of $1,500,000 as follows: 55 per cent or $825,000 to be secured from sewer rentals based on water consumption; and 45 per cent or $675,000 to be secured from sewer

rentals based on assessed valuation of taxable real estate. That part of the sewer rent based upon water consumption to produce the required revenue of $825,000 was computed on the basis of a ten-year average consumption and resulted in a general charge of 40 per cent of water bills. That part of the sewer rent based upon the total of taxable real estate of $927,268,080 as set forth upon the assessable rolls of the city of Buffalo resulted in a rate per $1,000 of assessed value of $0.727944824, or roughly a ¾-mill rate.

During the 12-month period ending June 30, 1939, the collections have amounted to 94 per cent of the total billing. The billings for sewer rents based on assessed valuation are made out by the Sewer Authority and collected by the Tax Division of the Treasury Department of the City of Buffalo. The sewer rents, based on water consumption, are made on the water bill by the Division of Water as an item in the regular billing, and collections have been made by the Division of Water and handed over to the Sewer Authority.

How this new method has worked out in general is best indicated by the following extracts from the 1938–1939 Annual Report of the Buffalo Sewer Authority:

"During the fiscal year July 1, 1938, to July 1, 1939, and in response to individual protests, investigations have been made of the premises of 135 consumers of water to determine the proportionate amount of each such consumer's water consumption reaching the sewerage facilities of the Buffalo Sewer Authority, and thereby to establish, in accordance with paragraph (e) of the Schedule of Sewer Rents, a basis for sewer rental charges. These consumers are located at 254 separate locations and represent 349 individual accounts.

"As a direct result of the investigations of the 349 accounts, it has been recommended that, (a) in the case of 103 accounts, sewer rental charges, based upon water consumption, be established upon an individually fixed proportionate basis, (b) in the case of 145 accounts, such charges be entirely eliminated, and (c) in the case of the other 101 accounts, such charges be continued to be made in the regular way and on the normal basis.

"These investigations have disclosed that 50 water consumers at 72 separate locations and involving 106 accounts are in whole or in part without connections to the public sewerage system; 19 accounts by reason of the nature of the water consumption and 87 accounts by reason of the absence of available or adequate sewerage

facilities. Septic tank systems have been found to exist or have been recommended installed at 39 locations where public sewerage facilities are not available.

"The following are some of the major industries covered by these investigations, together with summarized data covering the individual accounts represented. [See Table 4.]

"In addition to the foregoing, investigations have been made of concerns consuming water obtained from sources other than the Division of Water of the City of Buffalo, and using the sewerage facilities of the Buffalo Sewer Authority for disposal of the waste products of such consumption.

TABLE 4

*Summary of Investigations of Complaints and Action Taken by the Buffalo Sewer Authority**

INDUSTRY	NUMBER COMPANIES	NUMBER LOCATIONS	NUMBER ACCOUNTS	REDUCTIONS ALLOWED	REDUCTIONS NOT ALLOWED	NO CHARGES
Railroads	8	101	110	34	47	29
Breweries	8	8	24	13	11	—
Ice Manufacturers	5	5	15	13	2	—
Malt Manufacturers	4	4	8	3	4	1
Soft Drink Manufacturers	2	2	5	5	—	—

* From 1938–1939 Annual Report of the Buffalo Sewer Authority.

"Four concerns have been found to be using water obtained from the Western New York Water Company and one concern has been found to be using water obtained from the Buffalo River, and all are using the sewerage facilities of the Buffalo Sewer Authority and sewer rental charges have now been established for such use.

"Thirty-eight concerns having or having had well water supplies on their property have been investigated with the resultant disclosure that twenty-one have abandoned the use of wells because of the unsatisfactory character of the water obtained therefrom; seven are using wells and disposing the waste water into a second well or into an adjacent water course; three are using wells and the water therefrom is bottled and sold, and seven are using wells and disposing the waste water into the sewerage facilities of the Buffalo Sewer Authority and sewer rental charges have been applied to cover this disposal."

General Summary of Existing Conditions

The chief objection raised to measuring sewerage service on the basis of metered water comes from industrial users where water is used that is not subsequently discharged into the sewer system and to this extent this measure is inaccurate. In the case of residential properties, lawn sprinkling represents the only important use of water that does not eventually reach the municipal sewers. In the case of railways only a small portion of the water used reaches the sewers and the same is true of certain industries.

Where sewer rentals have been adopted the public has generally accepted them. In this respect 85 municipalities reported public opinion of rate structures as follows: 40, very satisfactory; 27, no complaint; 10, very few complaints; 4, complaints by certain classes; 4, too high. Most of the complaints emanated from industries, and it is quite conceivable that under any common rate structure some industries would be penalized severely while others would escape paying their fair share of the sewerage costs. In certain cities a clause has been inserted in the sewer rental by-laws giving power to establish special rates for industries. Such rates depend on: (1) the concentration of the sewage; (2) the percentage of water used but not discharged into the sewers; and (3) the quantity of water obtained from private supplies. In some cases industries have been charged on the basis of the number of employees.

Out of 100 municipalities reporting, 27 sent out monthly bills, 2 bi-monthly, 22 quarterly, 14 semi-annually and 24 annually. Obviously the number of bills to be issued depends largely on the basis of the rate structure adopted.

Out of 97 municipalities reporting, 51 indicated that the sewer rental was paid direct by property owners, 34 by occupants of the property and 12 by either property owners or occupants.

The water bill is the most frequently used medium of billing sewer charges not only when metered water is the basis of the rates but under all types of rate structures. The reports of 53 municipalities on their methods of billing are shown in Table 5.

The state laws vary widely on the specific purposes for which sewer rentals can be expended. In the states of New York and Ohio the revenues must be used first of all to operate, manage and maintain sewers and treatment plants, and any surplus may be used for enlarging existing structures or for debt service. In Wisconsin such

funds can be used only for operation, maintenance and repair. In Iowa the revenues may be used to finance operation, maintenance or construction. Some states forbid the use of sewer rentals for extending sewers into unsewered areas. In Kansas the law provides that the money derived from sewer rentals shall be used only for operating, renewing or extending the sewer system. The purposes for which sewer rental revenues are used, based on information supplied by 42 cities, is given in Table 6. From this information it will be noted that 4 cities use practically the entire amount collected for debt service while 16 use no part of such revenue for that purpose. Generally sewer rental revenues are used to pay the expenses of

TABLE 5

Data on Methods of Billing as Reported by 53 Municipalities

METHOD OF BILLING	TOTAL NO. OF CITIES REPORTING	BASIS OF RATE STRUCTURE					
		Metered Water	Plumbing Fixtures	Type of Property	Plumbing Fixtures & Type of Property	Connections	Uniform Rate
Separate bill	14	7	3	2	2	—	—
Separate bill attached to or sent with water bill	2	1	1	—	—	—	—
Separate item on water bill	31	22	1	2	3	2	1
Included in water bill	6	5	—	1	—	—	—
Total	53	35	5	5	5	2	1

operation, maintenance and administration and infrequently for enlarging or extending the sewer system.

In many cities the revenues collected are sufficient to pay only a part of the cost of providing, operating and maintaining the sewerage facilities. Such additional funds as are necessary are usually obtained from general revenues. In other places, however, the entire cost of maintaining and operating the sewers and treatment plants and for debt services is paid from sewer rental funds and in some cities it is even possible to expend a part of the revenue for other municipal activities. In some states law prohibits the diversion of sewer rental revenues to other activities.

Legislation Necessary

It has been shown that as far as Ontario and most of the other provinces of Canada are concerned, enabling legislation will have to be passed to permit municipalities to collect revenue on the sewer rental basis. Such legislation should clearly define whether or not the following are to be included under sewer rentals:

(1) The annual fixed charges on capital cost of constructing a sewer system whether separate or combined;

TABLE 6

Disposition of Sewer Rental Revenues, As Reported by 42 Cities
(Figures represent the number of cities)

PERCENTAGE OF TOTAL SEWER RENTAL REVENUE	ADMINISTRATION	OPERATION	MAINTENANCE	REPLACEMENT	SEWER DEBT SERVICE	ENLARGEMENT OF EXISTING SYSTEM	EXTENSION TO UNSEWERED AREA
1– 5	9	3	7	12	1	—	2
6– 10	13	2	7	3	2	2	3
11– 20	8	7	11	2	1	4	2
21– 30	2	7	5	1	3	—	2
31– 40	—	5	3	—	5	—	1
41– 50	—	4	2	—	4	—	—
51– 60	—	4	—	—	4	—	—
61– 70	—	2	—	—	1	—	—
71– 80	—	3	—	—	—	—	—
81– 90	—	1	—	—	1	—	—
91–100	—	—	1	—	4	—	—
Totals	32	38	36	18	26	6	10

(2) The annual fixed charges on capital cost of constructing a sewage treatment plant;
(3) The operation and maintenance cost of a system of sewers whether separate or combined;
(4) The operation and maintenance cost of a sewage treatment plant;
(5) The basis of a sewer rental charge;
(6) To what extent, if any, certain properties are to be exempt from a sewer rental charge.

From a consideration of the wide variation in the rate structures adopted by many of the states in the United States it is clear that

careful consideration must be given to a rate structure that will be equitable to all property owners. It would also seem that careful consideration should be given to the possibility of placing the construction, maintenance and operation of the sewerage and sewage treatment systems under the same municipal authority as controls the water works system where the revenues are collected in the water works bill.

The writer is of the opinion that the water consumption method is the proper one around which this rate structure should be built. This should be a comparatively simple matter in municipalities that are almost wholly metered, but where this does not exist, the rate structure would have to be extended to include the basis of charge set up as a percentage of the water bill where flat rates exist. Adjustments would have to be made for certain industries.

The provisions of such a rate structure should apply to all properties including those at present exempt from general taxation. If such exempt properties are called upon to pay for the amount of water consumed it would appear reasonable to charge for collecting and treating the sewage from them.

In any enabling legislation enacted, provision should be made whereby all by-laws on sewer rental charges should be approved by some central authority such as the Municipal Board where the Province of Ontario is concerned. The Municipal Board should also be given power to settle any dispute that may arise regarding charges to be made for taking the sewage from areas outside the municipal boundaries, where the contending parties are unable to arrive at a satisfactory agreement.

A word of caution seems to be in order as a concluding item to this paper. The erection of a rate structure for sewer rentals is not an easy matter. The prime consideration should be an equitable charge covering fully the service rendered and benefit derived. Unless the structure is wide and flexible inequalities are bound to arise, so ample provision should be made to permit adjustments where unusual conditions exist. It should also be borne in mind that sewer rentals have to a certain extent been adopted as a means of collecting revenue from properties that are exempt from general taxation. From a legal viewpoint, the charge should be equitable, and if the charge is not equitable the courts should not sustain it.

Additions and Changes at Fredericksburg

By Roland J. Leveque

THE much needed addition to the Fredericksburg Filter Plant, embracing many features in design which were planned by Fredericksburg's engineering staff under the supervision of L. J. Houston, Jr., City Manager, was completed on August 10, 1939. Plant capacity was increased from a normal rate of 2 million gallons per day to one of 6 m.g.d. This 6 m.g.d. rate is, however, greater than present demands, therefore the plant is being operated at a 4.8 m.g.d. rate.

In this enlargement program as in others, there were many phases involving the usual, accepted methods and items in design and construction, hence the writer will not dwell on these to any great extent. In lieu of presenting detailed data on the entire project, a brief summary of the enlargement program will be given, and this should give the reader a general idea of what has been accomplished.

The additions made were:

(1) Construction of two additional settling basins and revamping of the old basins.

(2) Changes in piping to reverse the flow in the basins, and the construction of four mixing tanks, each equipped with a slow mixing device.

(3) Construction of brick stilling walls in each basin.

(4) Installation of adjustable weir plates in settled water collecting trough.

(5) Erection of steel wash water tank of 50,000 gallons capacity.

(6) Construction of new clear well holding 220,000 gallons. This is a covered tank located outside the plant building.

(7) Four new 1.0 m.g.d. filter units equipped with hydraulic valves, operating tables and mounted gages.

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(8) Four old 0.5 m.g.d. filters converted from manual control to hydraulic.

(9) Construction of new building of brick and concrete, housing new units, office, laboratory, pumps, and providing ample storage space for chemicals in carload lots.

(10) Installation of two new chlorinators and one ammoniator.

(11) Installation of four additional pumps, two low head and two high head.

(12) Meters installed on raw and wash water lines; also a reservoir level recording meter.

(13) New laboratory with additional equipment for making chemical and bacteriological tests.

Every one of the items mentioned above can be regarded as an improvement. Of these, two have been selected as most likely to provide interesting material, not only because their value has already been proven, but also because either could be installed in existing plants at an expense that should not prove prohibitive.

Slow Mixers

The importance of pre-conditioning water before it reaches the filters is being stressed more than ever in the technical literature. The correct proportioning of chemicals, of course, remains paramount, but if a structure be poorly designed or have inadequate mixing facilities, it is unlikely that maximum benefits can be obtained even with the most careful addition of chemicals. The effect of a gentle mixing of the floc by paddles, whether in the laboratory or in the plant mixing tanks, shows such an improvement in floc formation that this method can neither be refuted nor ignored. It follows that any device which brings about an improvement is certainly to be desired, but when it effects economies as well, its adoption is just about a necessity.

Before presenting any figures to show the saving in chemicals since the installation of coagulators, this apparatus as installed at Fredericksburg will be described briefly.

There are four tanks for slow mixing, one for each settling basin. Each tank is equipped with a coagulator which consists of a horizontal shaft running lengthwise of the tank, and supporting three separate sets of paddles driven by a 1.5 h.p. motor with speed reducer attached. The peripheral speed of these paddles is 1.2 ft. per sec. Between

each set of saddles is a wooden baffle extending from the water line down to the shaft.

The detention period in these tanks is from 30 to 40 min., and the gentle stirring by these paddles results in a well formed and rapid settling floc. From these tanks the water passes into the settling basins through openings in a brick stilling wall which gives an excellent distribution. Prior to the installation of the slow mixing units it was difficult to get water of low turbidity coming in on the filters without using excessive dosages of chemicals. (See Table 1 for results.)

This saving in chemicals becomes more significant when it is realized that the saving took place at a time when construction work

TABLE 1

Fredericksburg Operating Data

	BEFORE INSTALLING COAGULATORS	AFTER INSTALLING COAGULATORS
Average Flow.....m.g.d.	2.43	2.36
R. W. Turbidity.....p.p.m.	68	60
R. W. Alkalinity.....p.p.m.	17	17
Alum Consumption.....lb./m.g.	208	143
Alum Saving.....per cent	—	21.6
Alum Saving.....5-mo. period	—	9.9 tons
Lime Consumption.....lb./m.g.	59	30
Lime Saving.....per cent	—	49.2
Lime Saving.....5-mo. period	—	6.2 tons

on the plant was still in progress, thereby introducing many factors which upset normal operating conditions and control. The writer feels confident that these savings will be substantially increased over present figures when more time can be given to study of the new plant operating demands.

It is regretted that data showing savings on wash water and other items cannot be presented at this time. In the short period of the new plant schedule, it has been virtually impossible to prepare comprehensive data of any accuracy or value. It is, however, reasonable to assume that when sufficient time has elapsed and material for an intelligent comparison has been accumulated, it will be found at Fredericksburg, as in so many other cities, that a

real economy is obtained right on down the line, when slow mixers are used.

Adjustable Weir Plates

After reversing the direction of flow in the settling basins, the former influent flumes were connected together to become a collecting trough, or effluent channel for the settled water flowing to the filters. Previous to the alterations, the settled water flowed over a weir to a depth of approximately 1 ft. In the new set-up, these submerged weirs were extended to the top of the sedimentation basins, leaving six openings in each basin, each opening being 2 ft. wide. These apertures are fitted with adjustable weir plates and guides of aluminum which can be raised or lowered to equalize the draw from all four basins. Water flows over these weir plates in a series of cascades, falling into the collecting trough which supplies the filters.

The advantages of these weir plates over the old submerged basin length weirs have become quite evident and are herewith given.

(1) An equalized draft from all basins is permitted.

(2) Cross currents and dead areas are eliminated.

(3) Flow through the basins is not affected by any sudden changes in velocity caused by starting or shutting down filter units.

(4) Only the uppermost portion of the settled water is skimmed off, since the head coming over these plates is maintained at approximately 1/4 in.

(5) When a basin is being refilled after cleaning, these plates can be raised so water will flow under them, thereby permitting the basins to be filled with clear settled water. During the period that one basin is out of service for cleaning and refilling, it naturally follows that the detention time in the other three has been reduced. Therefore, filling the basin from the back end with settled water, does not rob the other three of their chemical charge.

Sterilization of New Mains at Springfield, Illinois

By S. T. Anderson

PREVIOUS to 1927 little thought was given to sterilization of water mains. They were laid, flushed and placed in service. No precautions were taken against contamination of the water in the distribution system during construction or repair, and regardless of how much care was taken at the treatment plants or stations, the water could become contaminated in the new system if the mains were not properly sterilized. This was especially true when the new construction happened to be a transmission line.

Without a doubt, the more care taken with the location and construction of the mains and services, the smaller is the problem of sterilizing the lines. A water main should never be located in the same trench with a sewer. It is good practice to locate the line not less than ten feet away from the sewer horizontally and six feet away vertically (distance depending, of course, upon the type of soil encountered), and the ideal practice, when the distance is less than this, is to install cast-iron pipe for the sewer line with some type of water-tight joints.

The first important item in the construction of a water main is to see that the pipe and fittings used are clean and free from all foreign matter. This is usually done by the use of an air cleaner followed by either a mop saturated with permanganate of potash or a spray applying a solution of the potash to the inside of the pipe, washing out the inside of the fittings with spray or mop, in time for it to dry before being used. Next precaution is to keep dirt out of the pipe while it is being lowered into the ditch. This can be accomplished by having a tight fitting hood of canvas over each end of the pipe to be removed from the spigot end just before the pipe is placed. At night

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the pipe should be protected by placing a test plug in the open end to keep out any animals or foreign matter that might get into the pipe. The use of a test plug will also keep out trench water which, in many cases, will rise in the ditch during the night unless continuous pumping is maintained to keep down the ground water. Very often this ground water is contaminated with sewage which, if it gets into the main, contributes greatly to the problem of sterilization.

As much care as possible should be taken to see that the main is laid on solid bedding so that the pipe will not break, as each repair job renews the possibility of contamination.

In the past years, many methods of sterilization have been tried in Springfield, Illinois. On the whole, most of these have been satisfactory, except for some cases where it has been almost impossible to get a sample of water that could be approved as safe for drinking purposes. In nearly all methods the main was first thoroughly washed, either from a fire hydrant or from a special connection at the end of the line. Then, in some cases sterilization was accomplished either by extending the pipe above the ground or, by means of special connections and a length of hose, running a full flow of the water from the main through the new pipe. The next step was to tap the main near the point where the water entered the new section of the system, and then connect this to the chlorine tank for the supply to the main. The chlorine solution from the distribution system as it entered the new line was controlled as to flow during the application of the chlorine so that it was applied in such proportion that the treated water entering the new main had a concentration of not less than 40 to 50 p.p.m. of chlorine. This sterilizing solution was allowed to stand at least 3 hours, and in many cases as much as 24 to 48 hours.

After this solution was thoroughly washed out, samples were taken and submitted to the laboratory to determine if coliform bacteria were present. In some cases the samples taken immediately after the chlorinated water had been washed out of the main were satisfactory while samples taken from the same line 24 hours later showed the presence of bacteria. In others calcium hypochlorite or a chloride of lime was tried, using it dry and placing it in the pipe as it was laid. This practice had its disadvantage in that it prevented flushing the pipe preliminary to disinfecting. The water was turned into the main and allowed to stand for about 3 hours before flushing and sampling. Table 1 shows the amount of calcium used in various pipe sizes.

It was the practice during these methods, if the first samples were not satisfactory, to repeat the chlorinating of the mains periodically until satisfactory samples could be taken from the system. In some cases this delayed connecting the new line into the system for several weeks, causing inconvenience to the consumer and expense to the department. This was especially true along a street being paved, where the old main was to be replaced with a new and larger pipe, and new services were to be cut over to the larger main. In some instances, highly chlorinated water was allowed to flow through the system for several hours, and this did solve the problem in a few cases.

One section of town, where 6- and 10-inch main was installed, resisted all attempts of sterilization. Since all the wells were dry in this section it was important that the water supply be made available as

TABLE 1

Amount of Calcium Hypochlorite Used in Pipes of Various Sizes

NOMINAL PIPE SIZE	CALCIUM HYPOCLORITE	NOMINAL PIPE SIZE	CALCIUM HYPOCHLORITE
inches	*ounces*	*inches*	*ounces*
4	$\frac{1}{8}$	20	$3\frac{1}{2}$
6	$\frac{1}{3}$	24	5
8	$\frac{5}{8}$	30	$7\frac{3}{4}$
10	$\frac{7}{8}$	36	$11\frac{1}{8}$
12	$1\frac{1}{4}$	42	$15\frac{1}{4}$
16	$2\frac{1}{4}$	48	20

Available chlorine—65 per cent.

soon as possible. To expedite the work, chlorine was maintained in the main by means of proportioning equipment feeding chlorinated solution. This was continued several weeks or until satisfactory samples could be found after the residual chlorine was reduced.

In trying to lessen the problem of sterilization in the Springfield system many makes of jute were examined. Most of these were highly contaminated with bacteria, but there was found one light colored jute from which samples appeared to be free from bacteria. This was used for several years, but last year the new jute from the company was found highly contaminated. First thought was to insert with the jute a few tablespoonfuls of dry permanganate of potash which it was hoped would go into a solution when the main was filled, thus destroying all bacteria in the jute. But this did not work satisfactorily. In some cases the jute was put in a sterilizer

in the laboratory, but while the jute thus treated was free from bacteria, when it left the laboratory it would become contaminated before it could be placed in the main, as it was impossible to get the men to use enough care and precaution.

In one instance it was found that the leather seats on the fire hydrants were contaminated and could not be sterilized with ordinary chlorine solution. In other words, after they were treated for a three-hour period, washed off and allowed to stand in water, the water would become contaminated.

This past summer a number of experiments and sterilization of quite a few mains with ordinary lime were effected. Treatment of the jute with dry lime was first attempted, but that did not prove very satisfactory, as all the particles of the jute could not be brought in contact with the lime. Now the jute is cut to the proper length for the diameter of the pipe for which it is to be used. The coils are suspended in a solution of lime water after they have been loosened up, and then taken out, dried and placed in boxes where they are covered with lime. The boxes are taken directly to the job and the jute is not removed until it is ready to be placed in the joint of the pipe. It is insisted that the pipe men wear gloves in handling the material. The first attempt with the use of lime for sterilizing was not satisfactory, apparently because the jute was contaminated a short time after the main was sterilized. When a sample was taken the water showed the presence of bacteria, apparently coming out of the jute into the main. On the last few jobs, the treatment as described above was first carried out, then a solution of from 100 to 1,000 p.p.m. of lime was pumped into the main. The services were connected without meters, and people were told to use the water for all purposes except drinking, but that it must be boiled. After sufficient water was used to show that all of the lime had been drawn out, the main was properly flushed and samples were taken. So far this method has proven satisfactory.

It is felt that most of the trouble with sterilization has been the presence of foreign matter into which the chlorine solution could not penetrate, and the necessity of using contaminated jute. It is possible, however, that the chlorine treatment following the treatment of jute, which method is now used, will be entirely satisfactory, but it is much easier to handle lime solution than chlorine and with the present equipment the lime can be better controlled.

Importance of Sampling and Studying the Water In the Distribution System

By A. T. Lundberg

IN THE average city or town the water department has a complete record of the condition and quality of the water as it enters the distribution system. The records covering the quality of the water as it leaves the system for use by the customer, however, are not as complete as the records of plant operation.

It is interesting to note that in the paper "Should Plumbing Installations Be Approved by the Water Department," presented at the last meeting of the Virginia Section, E. F. Dugger made the following statement: "Water works departments have thoughtlessly maintained that the liability as far as they are concerned ceases at the meter." The true nature of the situation was brought to the attention of the water works departments this year when a court in Massachusetts held that they were liable beyond that point. As a result of the ruling it is evident that there is an inclination to hold the water departments responsible for the quality of the water furnished to the customer. The responsibility refers not only to the distribution system, but also to the fixture from which the water is obtained. In the event that the court ruling is upheld, it will definitely place upon the water department a responsibility which requires complete and accurate control of the conditions of the water until it is used by the customer.

Some of the ways the water in the distribution system may become contaminated are: (1) improper sterilization of new mains; (2) inadequate flushing of dead-end mains and fire hydrants; (3) connections to an outside independent water supply not controlled; (4) cross-connections which give the back siphonage of plumbing

A paper presented on September 8, 1939, at the Virginia Section Meeting at Charlottesville, Va., by A. T. Lundberg, Chief Engineer, Arlington County Water Department, Arlington, Va.

TABLE 1

Data on the Maintenance of the Quality of Water in Distribution Systems in Virginia

WATER SYSTEM	SOURCE	MILES OF WATER MAIN	AREA SERVED	SAMPLING STATIONS	WHEN TAKEN	FIRE HYDRANTS	HYDRANT FLUSHED	DEAD ENDS FLUSHED	PLUMBING INSPECTION	CROSS-CONN. SURVEYS
			sq. mi.							
Arlington County	Federal Supply, Washington, D. C.	151	25	20	4 weekly 8 biweekly	800	Yearly	As needed	Plumbing inspector	No survey
Bristol	Springs	25.42	2	2	2 monthly	186	Monthly	Monthly	Plumbing inspector	No regular interval
Charlottesville	Mt. Stream, Moorman's River	51	10	5	3 weekly	227	Twice yearly	Twice yearly	Plumbing inspector	—
Clifton Forge	Smith Creek	15	2.50	2	Daily	100	Monthly	Have none	Building inspector	City owned & operated
Danville	Dan River	70.84	5.82	8	Daily	422	Twice yearly	2 weeks in summer	Plumbing inspector	No survey
Fredericksburg	Rappahannock	24	2	—	Weekly	200	Not very often	As needed	Not regular (Sanitary Officer)	Not necessary here
Harrisonburg	Gravity	48.44	3.5	1	Weekly	180	When needed	When needed	Water Dept's. Plumbing inspector	Not needed
Hopewell	Appomattox River	56.47	5	—	Daily & federal monthly	533	4 times yearly	4 times yearly	Plumbing inspector	Only have one
Lexington	Moore Creek	10.66	—	Various domestic taps	Weekly	97	Quarterly	As needed	Plumbing inspector	One recently

Lynchburg	Pedlar River	136	13.93	1	Daily	762	Yearly	Weekly in summer	Plumbing inspector	No periodic survey
Newport News	Impounded lakes	260	30	12	Weekly	443	Twice yearly	Seasonal	Plumbing inspector	Constantly
Norfolk	Impounded lakes	390	25	2	Every 8 hours	457	As required	As required	Water Department	Continuously
Petersburg	Appomattox River	85	8.5	5	Daily	590	Yearly	Three times a week—some daily	Plumbing inspector	None; only 1 system
Richmond	James River	386.52	25	52	Always tri-monthly	2,542	Daily 2 monthly Monthly (87)	Daily 2 monthly Monthly	Plumbing inspector	No regular inspection
Roanoke	Impounded springs & wells	205	12 to 15	10	Daily	872	Weekly Monthly Quarterly Semi-annually	Weekly Monthly Quarterly Semi-annually	Water Department	Twice a year
Roanoke Rural District	Spring water	75	10	2	Three times daily	30	Twice yearly	When necessary	No plumbing inspector	Never investigated this
South Norfolk	Purchased from City of Norfolk	—	2¼	—	—	70	—	When necessary	Plumbing inspector	Done by City of Norfolk
Salem	Well, lake and river	24	5	Plant only	Once a day	150	Yearly	Three times a year	Plumbing inspector	Have only 2 on system
Waynesboro	Coyner Spring	20	6	None	Semi-monthly	120	As needed or yearly	As needed	Plumbing inspector	When needed
Williamsburg	Deep wells	10	1.50	Various taps	Twice weekly	80	Monthly in summer	Monthly in summer	Water Department	—
Winchester	Limestone springs	40	4.3	4	3 times weekly	183	Twice yearly	Twice yearly	None	Quarterly

fixtures under certain conditions. A brief description of the Arlington system and an experience, there, with a dead-end main will be presented here as illustrative of some of the problems to be encountered.

The water works in Arlington, which is ten years old, is composed of two pumping stations, standpipes, and a distribution system, delivering filtered water to the consumer in Arlington. This water is purchased from the Federal Government at the Dalecarlia Filter Plant in Washington, D. C.

Last September a condition arose in a dead-end main which showed the presence of an intermediate organism belonging to the coliform group. This condition was reported by the U. S. Public Health Service in a sample taken by them at the airport. An inspection was made and additional samples were taken. Analysis was performed at the Dalecarlia laboratory by Carl J. Lauter, Chief Chemist. The results showed the presence of an intermediate organism which indicated fecal or nonfecal pollution. Mr. Wood of the Builders Iron Foundry Co., who was in Washington at that time, fortunately had a chemical feeder with him. This was installed on the main and the treatment applied in various amounts for a period of six hours. To get the solution through the main a fire hose connection was made to the hydrant on the end of the line and allowed to flow wide open. The connection of the chemical feeder to the main was simplified by the location of a pressure regulator at the place where application was made. The pressure gage on the outlet side of the regulator was removed and the discharge of the feeder connected. Inasmuch as the flow through the main could not readily be determined, the exact rate of application cannot be given; however, the amount of calcium hypochlorite put into the main was as follows:

(1)	10 gal. of water—10 oz. H. T. H.....	5,000 p.p.m.
(2)	10 " " " 15 " " " "	7,500 p.p.m.
(3)	10 " " " 20 " " " "	10,000 p.p.m.
(4)	10 " " " 30 " " " "	15,000 p.p.m.

A definite residual was obtained on the end of the line.

This application was made under the supervision of Mr. Lauter and cleared up the condition. There has been no trouble since that time. The chemical feeder, was subsequently purchased by the county and is now part of the plant's regular equipment.

As a result of this experience, the matter of a definite water sam-

pling program on the entire distribution system was taken under consideration. A plan was discussed with Mr. Lauter, who agreed to make the analysis, and submitted to the State Health Department. Some samples had been taken prior to this time but no definite plan was followed. Under the present arrangement, there are 20 sampling stations, at 4 of which samples are taken weekly and at 8 bi-weekly, totalling 12 samples each week. These samples are taken each Monday and delivered to the Dalecarlia Laboratories. The results obtained from the laboratory are reported to the local and state health departments. It is felt that with the present arrangement the condition of the water in the entire distribution system is known at all times.

In preparing this paper the writer sent out a number of questionnaires to find out what other cities and towns in Virginia were doing. The tabulation of replies is presented in Table 1. It is interesting to note the variation in the number of samples taken compared to miles of water main, and also the varying frequency of the sampling. It does seem that there should be some more or less definite standard made for the different types of districts.

In establishing a definite sampling arrangement there is no reason why uniform forms could not be used and copies furnished the state health department, thus giving that department a complete record of the distribution system as well as the plant operation, which in most states is now reported on their forms. Some provision should also be made to help the small water works systems when difficulties of the type described arise. If a chemical feeder and a supervisor were made available to be used in emergencies, many small difficulties could be cleared up before they became serious. The delivery of good water to the customer is the important function of every water works department, and to accomplish this end requires the complete control of the distribution system in every phase of its operation.

Centralized Laboratory Control for a Group of Privately Operated Water Supplies

By John S. Kneale

THE Flatbush Consolidated Laboratory of the New York Water Service Corporation is rather unique in that it exercises laboratory control over about twenty separate public water supply systems on Long Island, four plants in upstate New York, two in New Jersey and analyzes occasional samples for several others. This centralized laboratory represents the consolidation of three smaller laboratories and has proved to be an efficient arrangement. A private utility company operating a large group of small water systems within a relatively small geographic area is in a position to use such an organization with considerable economy, as well as to effect a system of sanitary control under one centralized management. The need for this type of laboratory is rather unusual in the case of municipalities, except for a few of the larger ones which have a somewhat similar organization, but their use is not at all uncommon in the case of private utility operating companies. It is the intention of this paper to outline the factors which make a laboratory of this type both desirable and practical, as well as to demonstrate their departure from the ordinary conception of a water works laboratory.

Let us consider the surrounding circumstances. First, the geographic location of these plants must be considered. The laboratory is in Flatbush, part of the Borough of Brooklyn, where is located the largest of the plants, and immediately adjacent is the next largest plant at Woodhaven. Eleven plants are on the south shore of Long Island extending from Merrick to Sag Harbor along the Montauk Highway. The most distant one is only 120 miles away. Seven of these plants are between the laboratory and Patchogue, a

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distance of 60 miles. Seven more are on the north shore extending from Sands Point to Port Jefferson along Route 25A, and Port Jefferson is only 75 miles from the laboratory. It is obvious, then, that the plants are easily accessible by automobile. The plants are divided for sampling into three routes: two are one-day trips, from Sands Point to Port Jefferson and from Merrick to Patchogue; the third is an over-night trip from Patchogue to Sag Harbor. The upstate and New Jersey plants mail all their samples to the laboratory and, since the postal service is exceptionally good, few of them are old enough to be affected bacteriologically.

Because of the accessibility of plants on Long Island, the laboratory has an automobile which can be converted into a traveling laboratory for nearly any type of chemical analysis except those necessitating the use of a balance. All bacteriological work, though, must be done at the laboratory. On regular routine trips only chlorine, pH and carbon dioxide test equipment is carried.

Schedule of Sampling

It might be well to point out the sampling schedule maintained. A trip is made to each of the Long Island plants at least once a month for a routine check by the chemist. In addition, each submits a distribution sample by mail once a month. This constitutes a basic schedule for plants having no particular problem. Flatbush which does not come under this schedule has a sampling schedule for its 25 sources of supply varying from daily to twice monthly, depending upon the existing condition involved. In the case of Huntington and Port Jefferson, where there are open reservoirs, weekly samples are submitted. A weekly sample is also received from the iron removal plant at Sag Harbor. These are all mailed in. The first two are for bacteriological examination and the latter for chemical examination. Only the Long Island plants are visited by the laboratory car; the others submit samples for both bacteriological and chemical analysis—Haverstraw and North White Plains on a weekly schedule; and Syracuse and Norwich, which have local process control laboratories, monthly, but simply for rechecking since the centralized laboratory acts in only a supervisory capacity. This just about covers the sampling schedule. In unusual circumstances, however, the laboratory is always prepared to make a thorough study of the condition and make a recommendation for its elimination or correction.

The type of water found at the plants lends itself readily to what might be considered remote control. The majority of them are well supplies and the purifying quality of the sand in the Long Island formation is quite well known. Bacterial problems are confined almost entirely to newly laid mains, secondary contamination of reservoirs or temporary disturbances due to the repair of wells or pumps. Since all the water is well filtered by nature before it is pumped, there is no necessity for filter plants in this section. The one exception is Sag Harbor where a pressure filter plant is used for iron removal. Two principal forms of treatment are used on the Long Island water supplies: chlorination and the application of alkali. Chlorination is used to control the iron bacteria and as a precaution against pollution by certain plants which are not completely protected by geographic isolation. Alkali treatment is applied to control corrosion. The apparatus for this chemical feed is usually automatic. At all plants employing treatment, operators are required to make daily control tests and to keep a record of chemicals applied and results secured.

In total, five Long Island plants employ chlorination: three for safety; a fourth as a precaution against bacteriological impurities where the water is exposed at one point to possible ground seepage into the excavated cistern-type coagulation basins; and the last to eliminate hydrogen sulfide odor.

As previously noted, the sanitary quality of the well water presents few operating or purifying problems. Corrosion (both red water and tuberculation) is, however, still a major problem which must be solved. Alkali treatments are installed at seven of the plants. Four use only lime, two, a mixture of caustic soda and lime and the last, soda ash. One plant uses aeration in connection with the lime treatment. The laboratory does its part during the regular routine sampling visits by checking pH, feed equipment, dosage and complaints. At that time all necessary feed adjustments for the maintenance of proper treatment, as determined in the laboratory by periodic corrosion experiments, are also made. To date this assorted collection of alkali treatments has been rather successful in eliminating red water complaints. It must be admitted, however, that tuberculation has not been completely eliminated.

External conditions, then, seem to justify the use of a laboratory of this type. Some discussion of the organization itself should further demonstrate its value. From the plants are obtained over

350 samples per month, most of which are collected by the laboratory personnel. Two college graduates specialized in the field of water purification, and a secretary who has been trained as a technician constitute the personnel. The company is quite proud of the fact that it has not attempted to turn plant managers or plant operators into purification men, but has obtained persons who are prepared for their work and are able to devote their entire time and talents to it. By centralizing, the company has eliminated the duplication of equipment and material which would be necessary if a small laboratory were maintained at each plant. The laboratory is equipped for microscopic work and prepares test reagents and standard solutions not only for its own use but also for plant operator's control testing. It must be remembered that delicate equipment and trained chemists have frequently been made the excuse for either ignoring sanitary and chemical control entirely or for having some disinterested laboratory make periodic analyses which too often are infrequent and cursory. In either case it is possible that a situation might occur, either bacteriological or chemical in nature, which, if discovered in time, might have been eliminated inexpensively, but which has been allowed to develop to a point where elaborate and expensive corrective measures are necessary. On this basis a centralized laboratory justifies its expense. Further considerations including the advantages of centralized management and research and the economics of large scale buying of equipment and material add to the desirability of the centralized control.

To describe the division of labor in the laboratory, it will be simplest to show what each person contributes to the whole. The technician-secretary handles all the regular secretarial work such as correspondence, typing of reports, etc., and in addition takes care of all the regular routine bacteriological analyses under the supervision of either of the chemists. The assistant chemist does nearly all of the outside work of the laboratory such as the routine monthly visits to the individual plants for a sanitary inspection and the collection of samples and field tests for residual chlorine, pH and CO_2. He checks, and corrects or replaces plant chemical equipment, that is, the test sets, feed equipment and purification records. Finally, it is his duty to confer with the plant managers to discuss complaints and the findings of the monthly sanitary survey of the property in connection with the New York State Rules and Regulations. The chemist in charge is directly

responsible to the company for everything done in or by the laboratory. In addition, the major portion of the routine laboratory work, as well as research and experimental work, is handled by him.

The analytical schedule is quite interesting. Once each month a sample of both raw and finished water from each plant is analyzed for pH, CO_2, total and phenolphthalein alkalinity, hardness, chlorides, iron and manganese. Although the last of these is omitted in many laboratories, it has been found that manganese can be far more troublesome than iron both from the standpoint of staining and for false chlorine residuals, so a continual check is kept on it, especially for Long Island where pockets of manganese-bearing water are not infrequent. It might be argued that unnecessary emphasis has been placed on the chemical quality of the water, but results obtained over the years have proved it quite valuable in detecting changes which have a direct bearing on the domestic and industrial utility of these water supplies.

The important role of any advisory department is to relay the information obtained as quickly as possible. In this matter the laboratory is quite efficient in giving the plant managers not only statistical results but interpretations of them. Upon completion of the analyses, if the results are satisfactory, a report is mailed to the manager and corporation consultant, George D. Norcom, who devised this system of control. If the sample proves to be unsatisfactory, both are notified by telephone and corrective measures are agreed upon. The findings are then confirmed by a regular report form.

The advantages of the centralized method of control may be summarized as follows:

1. Expert sanitary supervision of all plants in the group, both large and small.
2. Monthly sanitary inspections.
3. Frequent bacteriological sampling by trained laboratory personnel.
4. Prompt attention to sanitary problems and complaints.
5. More complete laboratory equipment and better qualified personnel than is normally available for a small water supply system.
6. Opportunity for research work.
7. Expert interpretation of reliable results.

Induced Slow Lactose Fermentation In Escherichia Coli

By Mary E. Caldwell

RECENT literature contains numerous reports of studies on slow lactose fermenters and discusses their possible sanitary importance. An investigation of certain phases of the oligodynamic action of copper on several members of the enteric group of bacteria was made possible by the United Verde Copper Company. Both recently isolated typical strains and American Type Culture Collection strains of these organisms were used. After exposure to metallic copper in concentrations of 0.1 to 1.0 parts per million in distilled water, for periods which varied from a few hours to several days, Endo agar plates were poured, incubated at 37°C., and colonies examined daily. Controls were made in each instance with copper-free water with the same inoculum, time interval, and medium. Only results with *Escherichia coli* will be included in this preliminary report. Detailed experimental data will be presented later.

Copper ions adversely affected the ability of *Esch. coli* to ferment lactose. After several hours of exposure to copper and subsequent growth on Endo agar plates for 18 to 24 hours, a few atypical colonies which were clear, colorless, smooth, and glistening appeared among the typical *Esch. coli* colonies. As the concentration of and duration of exposure to copper increased the colorless colonies became more numerous until an entire plate often resembled typical *Eberthella typhosa* colonies rather than *Esch. coli*. Conditioned by the period of exposure and copper concentration, all color gradations conceivable in *Esch. coli* colonies were observed; they varied from the bluish-colorless ones through shades of pink and red but the latter with a few exceptions were without a metallic sheen. The

A record of research contributed by Mary E. Caldwell, Head, Department of Bacteriology, University of Arizona, Tucson, Arizona.

ability to produce luster was the first characteristic to be lost and although after 36 to 48 hours some of the pink forms attacked lactose with more vigor, at no time did even these regain their metallic appearance. Occasionally, 24 to 48 hour-old colonies with a pinkish periphery gave rise to a small central red area with a definite luster. Pink and colorless papillae were sometimes seen; variants will be described in the forthcoming publication. Microscopically, individual cells were often coccoid.

Another rather striking method to demonstrate this inhibition of, or delay in, lactose fermentation was found when two or three sterile, 10 mm. by 6 mm. fragments of so-called "air blown copper" were placed in a Petri dish and *Esch. coli*-inoculated Endo agar poured into each plate. In an area which immediately surrounded the copper, few colonies developed but in a more peripheral zone, 10 to 12 mm. in width, there was a gradation from complete failure to utilize lactose to more and more vigorous fermentation as distance from the copper was increased. However, the number of colonies in this zone was comparable to more distant areas in the plate. Outside the zone which affected lactose fermentation, typical red colonies with their metallic luster were found.

Colorless and pale pink colonies on Endo agar plates failed to ferment lactose bouillon; when evidence of lactose utilization in Endo's medium became apparent, weak and slow fermentation of lactose bouillon occurred somewhat irregularly. Litmus milk cultures either showed no change or became alkaline. Other sugar reactions will be reported later. Methyl red tests were usually negative, indol not produced, and nitrates not reduced.

An experience in another laboratory where a copper water still was in use suggests the advisability of a determination of the relative freedom from copper of the distilled water employed in the preparation of media. Any substance which produces such atypical *Esch. coli* colonies that recognition is defied at the time of ordinary routine water analyses becomes a problem of no little interest and importance. From these results it would seem highly desirable to investigate various factors which might influence the all important fermentation of lactose bouillon by *Esch. coli* when the potability of a water supply is under consideration.

The writer is indebted to Grant Anderson for technical assistance and to Oliver C. Ralston for the copper compounds and various analyses.

Water Works Intakes

By Norman G. McDonald

IN WATER works practice the word "intake" usually means that portion of the water works system which conveys the water from the source of supply to a gate house, pumping station or other portion of the water works plant. There are a few water supplies taken from the shores of lakes or rivers by the excavation of a channel, such as at Ottawa, but in this paper only intakes having an under-water conduit will be considered.

The intake should have sufficient capacity to meet the demand for water under all conditions and should be capable of supplying water of the best quality economically obtainable with due regard to treatment processes.

Unlike most parts of the water works system the intake is rarely constructed in duplicate and its failure generally means the failure of the supply of water. Its design and construction is therefore of great importance. Should the intake fail through the inlet's being blocked and the available means for removing the blockage not be effective, the operator is faced with taking drastic action to secure water. In two municipalities taking water from Lake Ontario, dynamite was used to open a hole in the intake pipe near the shore when ice could not be dislodged from the inlet. Such action appears drastic but under the circumstances may have been warranted. The operators were not justified, however, in failing to repair the breaks properly and in continuing to draw into the system polluted water from near shore, particularly in one case where chlorination was the only form of treatment.

The greatest hazard in the operation of intakes in Canada is that due to frazil ice. On bodies of water subject to wave action, in which the sheet ice is broken up during its formation, frazil ice is formed

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and may be drawn into the intake by eddies or other currents. With low temperatures and high winds this ice may be formed in such quantities as to shut off completely the supply of water. Anchor ice which forms on the bottom, or on the intake itself if the water temperature at that point becomes sufficiently low, may also cause trouble. If the intake is located near the mouth of a stream, floating ice may be brought down by flood waters in such quantities as to interfere with the operation of the intake. As ice is only slightly lighter than water, only a slow current is required to cause it to flow with water, particularly if it has been broken into small pieces.

Floods in rivers or winds on lakes may set up currents capable of drifting material along the bottom of the lake or river. This may allow sand or other debris to gain access to the inlet unless it is well above the bottom; also, part of the intake may be undermined which action may cause breakage and failure.

The original intake at Port Hope had a turned up inlet extending only a short distance above lake bottom. The depth of water at this point was about 14 ft. and southwesterly winds made the water quite turbid, thus setting up currents which drifted fine sand and silt along the bottom. A great deal of this silt came into the well not only through the inlet but gained access to the pipe through numerous open joints so that ultimately the intake pipe filled up to such an extent that it had to be abandoned and replaced by a new pipe.

In the Toronto vicinity easterly winds frequently continue for several days and set up strong currents flowing in a southwesterly direction parallel to shore. These currents continue for some time after the wind has ceased or changed direction. While making the survey for the Victoria Park intake in 1925 the author measured a southwesterly current in excess of 1 m.p.h. at a distance of $\frac{1}{2}$ mi. from shore. On this particular day there was a light breeze from the west but an easterly wind had been blowing on the two previous days. Such a current might be quite capable of eroding fine sand if its path were partially obstructed.

One of the Toronto intakes is in the path of this current and continuous vigilance and frequent under-water inspection have been found necessary to insure safety of operation. This intake is 6 ft. in diameter and was laid in a trench in the sand bottom in 1893 and 1898. In the years 1911 and 1921 sections were undermined and collapsed. These portions were replaced on wood pile bents, steel sheet piling was driven to a depth of about 10 ft. below the invert of the pipe on both sides and the space was filled with concrete.

Locating the Intake

The selection of the location of an intake is the first and frequently the most important step preceding its design. The topography, drainage of the adjacent lands and sewerage system of the surrounding areas should be studied as well as the currents in the lake or stream forming the source of supply in order that the pollution may not be excessive and that the water may be as pure as economically and practicably obtainable.

The physical and chemical qualities of the raw water are important particularly from the economic standpoint as they influence the cost of treatment. Vegetable matter and chemicals such as phenols and creosols may cause tastes which are difficult to remove. The provision, however, of a safe water for domestic consumption is more dependent upon the bacteriological quality of the raw water. The question naturally arises as to the extent to which raw water can be polluted without overloading the treatment process. In this regard the International Joint Commission on the Pollution of Boundary Waters states that in its judgment a purification plant would be overloaded if the coliform organisms in the water delivered to the plant are more than 500 per 100 c.c. on the average or if in $\frac{1}{10}$ c.c. samples coliform organisms are present 50 per cent of the time.

The above statement should be accepted only in a general way as in certain cases a water might meet this specification yet be so highly polluted for short periods it could not be safely utilized with any form of treatment plant. Such a condition might exist in a large lake where a wind or current in a certain direction carried sewage directly to the intake.

The accepted bacteriological standard of drinking water after treatment on this continent is that of the U. S. Treasury Department which requires that the water shall not contain more than one coliform organism per 100 c.c. or more than six coliform organisms per 100 c.c. for 5 per cent of the time. In keeping within the requirements of this standard the permissible amount of pollution in the raw water supply will, within limits, depend upon the efficiency of the treatment process. If chlorination alone or sand filtration alone is provided, Streeter has stated that the coliform index should not exceed 50 to 80 per 100 c.c. in the raw water. If, however, the two processes are combined a raw water with a coliform index not exceeding 5,000 per 100 c.c. may be accepted. It is quite evident that even with the highest degree of water purification now available there

is a definite limit of raw water pollution beyond which a safe drinking water cannot be produced. Moreover, there is always a hazard in the treatment of highly polluted raw water due to possible lapses in the treatment process, particularly in the application of chemicals.

Heavy pollution usually comes from sewage and therefore intakes should as far as practicable be located upstream from sewer outlets. This is usually a simple matter for a river supply but in a lake it can rarely be done, although advantage can be taken of prevailing currents, distance and depth of water. Unfortunately under favorable conditions sewage may be carried by winds and currents for long distances. This is particularly true where the temperature of the lake is much colder than that of the sewage being discharged into the lake. In such cases the pollution may at times be very high so that its reduction by sewage treatment must be assured before the location may be safely selected for an intake.

The depth of water is an important consideration as it reduces hazards due to ice. Depth also decreases the variation in water temperatures which factor is an important consideration under both summer and winter operation. In navigable waters intakes should be, if possible, off the shipping routes in order to reduce the pollution resulting therefrom and to avoid possible interference through the dragging of anchors.

Intake A, as shown in Table 1, was laid in the years 1893 and 1894. It is 24 in. in diameter and 2,500 ft. in length, of riveted steel construction with flanged joints and laid on the soft clay bottom of Lake Ontario to a maximum depth of 63 ft. In 1936 after 42 years of service the pipe was caught by a ship's anchor and a riveted circumferential seam torn open. A section had to be taken up and repaired.

Designing the Intake

Intake designs vary according to the nature of the body of water in which the intakes are placed. The withdrawal of water from a small deep lake that freezes over very quickly presents very little difficulty in comparison with that required in a shallow fast flowing river.

The inlet end of an intake may be of any one of a number of types. The common type of inlet for small systems is simply an elbow turned upwards, quite often with a screen on top. This may serve satisfactorily where the water is quiet and deep but the screen if fine

enough to be of any use is apt to become clogged and under conditions of high flow, eddy currents may form over the top of the inlet pulling down ice in winter and warm water in summer.

A submerged crib with single or multiple inlets is generally used. The crib is made of sufficient size that it can be supported on the bottom of the lake or stream without undue settlement. In lakes the crib usually contains an inlet consisting of an elbow and bellmouth facing upwards and over this is placed a steel or concrete cover plate to form a square or cylindrical inlet of large area and consequently low velocity. The height of the opening should be small in comparison with the diameter. This type of inlet has the effect of drawing water on a horizontal plane as near the bottom as is practical and it effectively prevents the formation of vertical currents and vortexes, thus reducing the hazard due to ice and the seasonal temperature of the water. In general design, it is quite similar in appearance, though opposite in action, to the hydraucone type of draft tube for water turbines which came into use about 25 years ago. The inlet shown in Fig. 1 is an example of this type.

TABLE 1

Data on Numerous Intakes

MUNICIPALITY	SOURCE OF SUPPLY	DIAM. OF PIPE	YEAR LAID	DEPTH OF WATER	AREA OF ENTRANCE	ENTRANCE VELOCITY	FLOW*
		Inches		*Feet*	*Sq.ft.*	*In./Sec.*	*Imp. M.G.D.*
A	Lake	24	1893 1894	63	4.9	32.0	7.0
B	Lake	14	1923	8	6.8†	4.9	1.5
C	Lake	16	1934	20	9.4†	4.7	2.0
D	Lake	30	1923	16	35.3†	5.0	8.0
E	Lake	30	1937	60	17.3†	18.0	14.0
F	River	48	1925	38	59.0	7.9	21.0
G	River	24	1935	7	7.5	7.4	2.5
H	Lake	72	1893 1898	60	63.6	28.0	80.0
I	Lake	96	1932	53	250.0†	8.9	100.0

* Flow on which velocity is based.

† Inlets with cover plates.

In rivers the horizontal cover plate on the inlet loses the greater part if not all of its value as the current of the river would be parallel

with the plate. A single large inlet projecting toward the middle of the stream may be quite satisfactory for small or medium-sized intakes.

The inlet for the intake shown in Fig. 2 is located in a large river in about 40 ft. of water. It consists of a conical steel pipe increasing from 4 ft. to a maximum of 8.67 ft. in diameter at the entrance, 25 ft. in length and supported on a rock filled timber crib. A ball and socket flexible joint connects this inlet structure to the 4-foot diameter steel intake pipe. The center of the inlet is 7 ft. above the river bottom and faces toward mid-stream so that the flow into the intake is at right angles to the river flow. With the water works at full

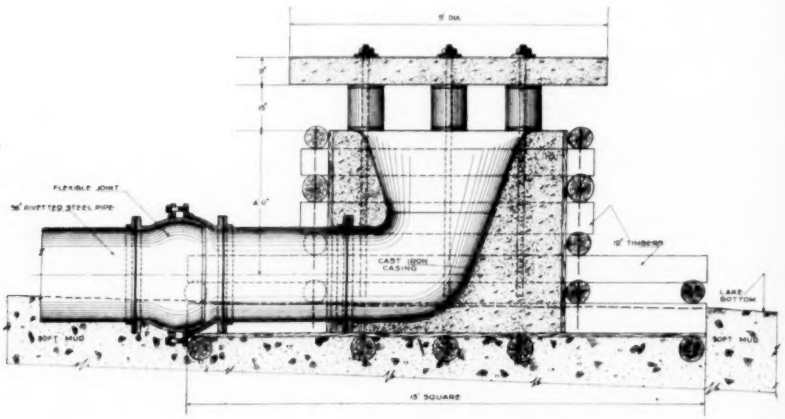

FIG. 1. An Intake Crib designed for use in a bay

capacity the velocity of entrance is 7.9 in. per sec. Some ice trouble at this location was anticipated and the inlet is such that ice can be dislodged with the minimum of effort through the reversal of flow from the pumping station. In the 13 years that this intake has been in service the inlet has been blocked by ice on nine occasions but has been cleared quite easily by reversing the flow.

For large supplies taken from rivers, and in a few cases from lakes, inlet structures projecting above the surface of the water with numerous inlet ports are frequently used. In these the ports are large and sometimes placed at various depths and positions so that water may be taken in where it is found to be most satisfactory. In all cases the inlet should be designed for the particular conditions under which it will have to operate.

The intake structure for one American city is in a large river where the water is normally 28 ft. in depth. It consists of a concrete wall 20 ft. thick and 110 ft. in outside diameter built on rock and extending to a height of 20 ft. above mean water level. The water enters through 12 ports each 6 ft. square located about 5 ft. off the river bottom and passes through 4 gates each $5\frac{1}{4}$ ft. by 6 ft. into the central vertical shaft leading to the intake tunnel. Frazil and anchor ice have caused considerable difficulty in the operation of this intake.

Inlets should be designed to give large entrance areas and consequently low entrance velocities. In bodies of water where there is no ice hazard a velocity of 2 ft. per sec. at the entrance may be quite satisfactory but under adverse conditions a velocity of 6 in. per sec. or even lower may be desirable.

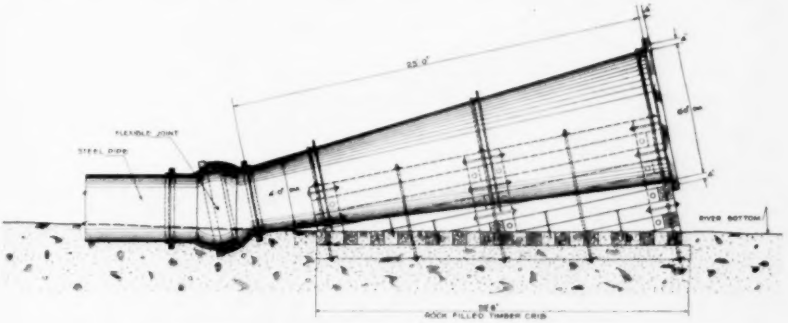

FIG. 2. An Intake Crib designed for use in a river

The entrance velocities and other data of some water works intakes in Ontario based on their designed or normal capacities are shown in Table 1.

Planning Conduits

Intake conduits are usually made of steel pipe although some of the very small ones are cast iron. Concrete or even tunnels, where the conditions are suitable, have also been used in the construction of large intakes.

Except for short intakes cast-iron pipe is usually limited to sizes up to about 16 in. in diameter because of its weight and the character of the material itself. For these small conduits the pipe may be ordinary bell and spigot with the joints calked under water or the joints may be of a flexible type in which a rubber gasket and bolts are used.

Steel pipe has a distinct advantage in strength and weight which enables it to be laid in sections up to 100 ft. in length. The small sizes are lap-welded in lengths of about 20 ft. but sizes over 12 in. are made from plates riveted or welded in about 30-foot lengths. The recent trend has been towards the use of pipe with butt-welded seams which presents a smooth interior with relatively higher carrying capacity.

The intake pipes for D and E in Table 1 are both 30 in. in diameter and made from steel plate. The former is of lap-riveted construction for both circumferential and longitudinal seams while the latter pipe is of butt-welded construction. Tests made after installation indicated a coefficient in the Williams & Hazen formula of less than 100 for riveted pipe and over 130 for welded. The difference in the carrying capacities of the two pipes is not altogether due to the difference in the joints as the coating on the riveted pipe was considerably rougher than that on the welded pipe.

The lap-riveted steel intake pipe A in Table 1 was tested some time ago and the coefficient was found to be 85. An examination of the interior of a section of this pipe which was taken up in 1936 indicated the steel to be in good condition. Any sediment, however, which might have been lying in the pipe would have been removed when the pipe was being taken out.

The old Sudbury intake is also a lap-riveted steel pipe 18 in. in diameter. Tests made about 2 years ago indicated a coefficient of only 60 which is extremely low even for a pipe nearly 30 years old.

The riveted steel intakes, H in Table 1, have coefficients of about 90. In intake I the interior is of concrete and is very smooth. Here a coefficient in excess of 140 is anticipated.

Intake conduits should, generally speaking, have a continuous rise from the inlet end to the well. Under certain conditions the water from lakes or rivers may contain a good deal of dissolved air even at considerable depth. As this water flows through the conduit the pressure is reduced and some of the air may be released. If the conduit rises this air will come through to the well, but if there is a high point in the conduit the air may become pocketed and thus reduce the flow.

A continuous rise on the intake also prevents the emptying of the pipe through stoppage at the inlet. As a steel pipe, except in very small sizes, has a tendency to float when empty this feature is of

importance in locations where there is a good deal of trouble from ice and the pipe is not covered or anchored.

In searching for reasons for the low capacity of the old intake at Sudbury a profile of the pipe was made which indicated an upward slope from the inlet to a high point about 175 ft. from the well where the pipe was 2 ft. above the outlet end in the well. It was thought that air might have been pocketed at this high point but on drilling a

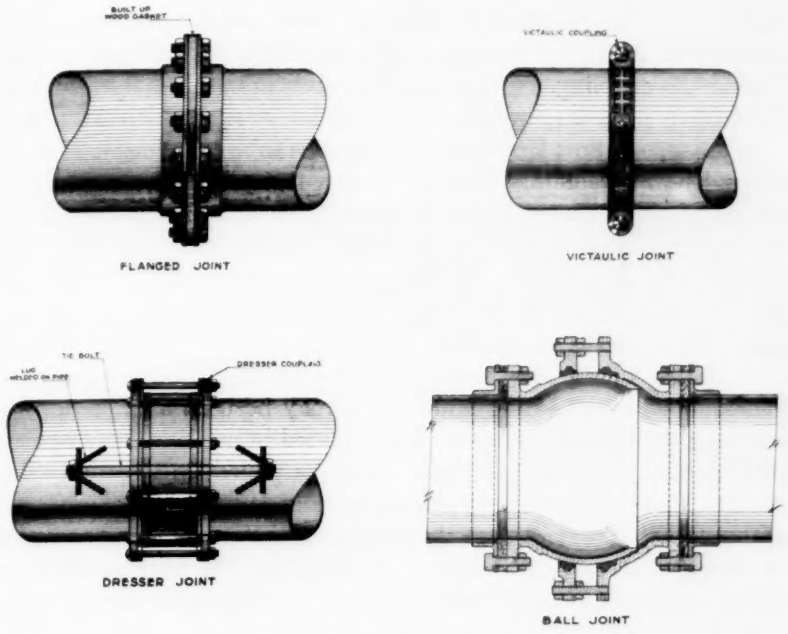

FIG. 3. Typical Intake Pipe Joints

hole through the top of the pipe no air escaped and there was no increase in capacity.

If it is not possible to avoid a high point in an intake conduit, provision should be made to extract any air which may accumulate.

There are several types of joints (Fig. 3) available for steel pipe. Their use depends to some extent upon the character of the surface on which the pipe is to be laid. Quite frequently the sections of steel pipe are attached together on the surface by means of flanges with rubber or wooden gaskets to form laying lengths of from 90 to 120 ft., and these longer lengths laid and joined together under water.

Wooden gaskets made of several layers of soft wood have the advantage that they may be tapered to form an angle in the pipe at the flange to fit the profile of the bed on which the pipe is to be laid and under water they are easier to handle than rubber. Flanges are not very satisfactory for under-water joints as even with wooden gaskets their flexibility is limited and there are many bolts and nuts to be placed by the diver.

Victaulic couplings have been used to some extent for under-water joints. Although they have the least number of bolts there is considerable difficulty in getting the pipe into proper position before placing the coupling. Unless the pipe ends are accurately centered a defective joint may result.

In the second Port Hope intake where victaulic couplings were used for under-water joints a steel frame was inserted in the end of the section of pipe which was laid to assist in centering the joint. After the joint was made this frame, on which a scraper was attached, was pulled ahead to the end of the new section by means of a cable placed inside the pipe, thus removing any mud which may have entered the pipe in the process of laying.

Couplings of the sleeve type, such as "Dresser," are quite convenient for laying, as the middle ring may be used as a socket for inserting the end of the pipe. When placed in position there is very little danger of leakage as the gaskets are pulled up tightly by the bolts. There is, however, nothing to hold the lengths of pipe together longitudinally except the friction of the gaskets, and to make certain that the ends of the pipe are close together in the joint, it is desirable in under-water work to tie the ends of the pipe together outside of the coupling by means of lugs and tie bolts. This coupling is flexible to the extent of four degrees deflection. Special angle couplings can be used as desired to fit the profile of the intake bed.

Couplings having a greater degree of flexibility, such as the ball and socket type, are useful where uneven settlement may occur, as at a crib after the pipe is laid or where there is danger of the pipe being disturbed. They are, however, expensive and are seldom required where conditions and the profile are accurately determined beforehand.

During and following the laying of the pipe line the profile of the pipe should be made to insure that the deflection in the joints is within safe limits.

Some form of anchorage is often necessary to prevent lateral displacement when the pipe is laid on shale or rock. The placing of concrete saddles over the pipe is not effective but the pipe should be anchored to the bottom. A 14-inch steel intake pipe (Fig. 4) installed in the winter of 1923 was anchored to the shale at each joint by means of two $1\frac{1}{2}$-inch "Fox" bolts inserted in holes drilled in the shale and tied together at the top by means of No. 4 galvanized wire twisted tight. Cloth cement sacks partly filled with a mixture of cement and sand were used to support the pipe between the anchor bolts at each joint and at such other points as were found necessary.

All pipe used for intakes as well as the couplings should be thoroughly coated to prevent rusting so as to increase the life of the work

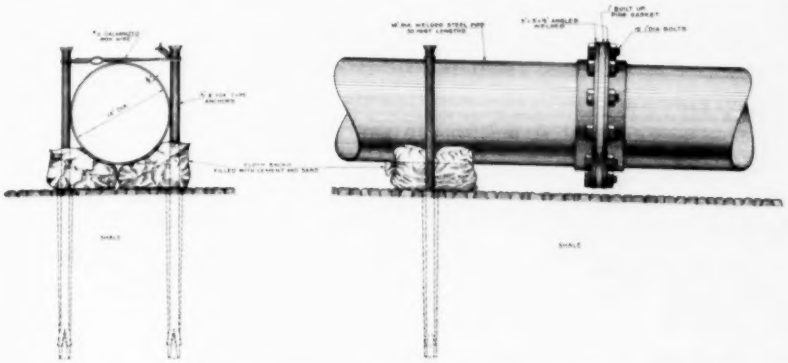

FIG. 4. Details of Anchorage of Steel Intake, 14 in. in diameter

and maintain high flow coefficients. For large supplies where conditions are favorable the conduit may be wholly or partly in a tunnel.

Using Wells for Discharge from Intakes

Intake pipes generally discharge into wells from which the water is pumped. These wells should be of sufficient size to accommodate the intake valve, screens and the suction pipes to the various pumps which may or may not be provided with foot valves. The inner end of the intake pipe is usually laid about 7 to 10 ft. below the low static water level but should be low enough to allow for the hydraulic slope required for the desired capacity. The well should be deep enough to give access to the bottom of the valve. If the intake is long and the velocity high, an overflow may be required to take care of surges

due to the sudden stoppage of the pumps. If the intake is short or the velocity low, such surge as may occur may be taken up by providing storage in the well above water level.

Wells should also be large enough so that when the largest pump is started the water level will not be drawn down too low before the flow in the intake accelerates to the required velocity. Any difficulty in this way can be overcome by opening the pump discharge valve slowly, which practice is desirable in any case.

Gate valves are installed on intake outlets to permit the unwatering of the well. Such valves are usually hand operated in the smaller sizes while the large ones are power operated. A quick opening valve, such as a gate valve operated by hydraulic cylinder, may be very useful when first putting the intake into service, particularly if the pipe has been laid on a muddy bed. At Belleville the mud was removed from the intake by quickly opening the hydraulic gate valve with the well unwatered. A velocity of over 5 ft. per sec. was generated before the well filled and this was sufficient to move the mud along the pipe. As soon as the well was filled the valve was closed, the well pumped out and the operation repeated until the water was clear. The well was then cleaned. If the top of the well is high enough above water level similar results can be obtained by filling the well with water from storage and generating velocities outward. This method may also be valuable for flushing ice out of the inlet although a pressure connection to the pipe behind the valve may be more useful if the ice blocks up the inlet port, as a considerable pressure may be required at the beginning. Where ice trouble is frequently experienced the installation of both methods may be justified. Wells in which chemicals are applied may be designed to create a spin or eddy to assist in the mixing of the chemical with the water before entering the pump suctions.

Some form of screen is installed in practically every intake well. Its purpose is to prevent fish, weeds, debris, ice, etc. from getting into the pumps. On small systems the screens are usually of the stationary type and may be in duplicate to permit their being removed and cleaned while the plant is in operation without allowing the screenings to pass into the pump suctions. In larger systems, particularly where there is a considerable amount of foreign matter capable of being removed in this way, power-driven revolving screens cleaned with pressure water sprays are used.

Constructing the Intake

In designing an intake the engineer should bear in mind the methods by which it will be constructed and the equipment required therefor. A diver works under a great handicap as, even if the water is normally clear, he stirs up enough mud to shut off the small amount of light which might otherwise reach his work. To increase his difficulty he has to wear gloves unless the water is warm. The design should permit as much as possible of the work to be done on the surface. Under-water joints should be as simple as possible and every part should be fitted before being lowered to insure an easy fit under water. All nuts should run freely on the bolts so that wrenches need be used only for tightening.

The methods of construction of intakes vary a great deal. In the Great Lakes and navigable portions of the rivers flowing into them, suitable floating plant can be obtained for almost any size of intake. The minimum of plant required consists of a derrick scow with spuds and a tug. For supplying air to the diver an air compressor and storage tank is desirable although a hand pump may be used.

For the construction of intake I, the available derricks were not large enough, so the contractor had to build and equip one for the job. This scow was 100 ft. long and 42 ft. wide and the derrick was capable of lifting 300 tons. There were three other derricks and three tugs used on this work.

There are many small lakes or rivers on which no floating plant is available and the intake has to be constructed by a different method. Sometimes small pipe to be laid on the bottom may be floated to its position and sunk. In this case numerous flexible joints are required. Fortunately, however, most of these lakes freeze over solidly and the intake may be laid quite easily through the ice during the winter months. In this method the shore end and the part of the under-water section in the trench are constructed during the summer or fall, a coffer dam being built out into the water. Then when the ice is sufficiently strong the balance of the pipe and the inlet are put into place, a diver making the under-water joints. The Sudbury intake in Ramsay Lake was constructed in this manner.

Intake costs vary to a greater extent than do costs of other parts of the water works system. Some pipes are laid directly on the bed of the stream or lake with little work on shore, while others are laid in trench throughout with various materials to excavate. The in-

take pipe C in Table 1, 16 in. in diameter and made up of $\frac{3}{8}$-inch steel plate welded and laid in trench throughout, cost about $10 per ft. under competitive tenders in 1934 when there was little marine work being carried on, while the intake pipe I in Table 1 cost about $140 per ft. A short time ago a contract was let for the supplying and laying of an under-water steel pipe line 8 in. in diam. at a price of less than $4 per ft. The pipe is to be laid on the lake bottom which is shale. It is to be fitted with sleeve type couplings at intervals of 40 ft. and anchored to the shale by "Fox" type bolts with galvanized wire ties.

The intakes referred to in this paper are, with a few exceptions, those with which the writer has had experience and are believed to be typical of intakes used for all water works purposes. Intakes for hydraulic power plants are somewhat different as the capacities are relatively very much greater and the quality of the water unimportant.

Use and Limitations of Conductivity Measurements Of Well Water Quality

By K. W. Brown

MEASURING the extent to which water conducts an electric current is a standard practice in many water works laboratories. The procedure is simple and rapid, and the results provide at least a rough idea as to the total mineral content of a sample of water. As a matter of fact, it appears from recent findings that conductance measurements can serve as a check on computed total solids and therefore as a check on the accuracy of a chemical analysis.

In applying conductivity methods to the measurement of well water quality it should first be emphasized that there is no need for more than a superficial knowledge of the underlying principles. The important thing to remember is that conductance is directly proportional to dissolved solids and that variations therein can be detected and measured quickly as well as accurately. Hence, if it is necessary to find out where hard and saline water is getting into a well, the simplest method is that of lowering a conductivity cell down the well and taking readings all the way from the top to the bottom. With proper equipment and favorable conditions in the well it is possible to detect variations in salinity and to reveal thereby the location and depth of contaminating strata.

It would be a waste of space to describe the various types of conductivity apparatus and the theories pertaining to their operation. Most of them, in one form or another, involve the familiar wheatstone bridge arrangement and are designed to measure the resistance rather than the actual conductivity of an unknown solution. Equipment for well measurements is the same in principle but requires in addition a long length of two-way conductor which is suitably insulated

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and strong enough to support the conductivity cell as it is lowered into the well. For our work we have found it best to use 1,000 feet of No. 18 rubber covered cord, Tirex or equal, wound on a hand operated spool and connected through a brush type of contactor to a Leeds and Northrup conductivity instrument of the portable type. The latter in turn is connected to a 110-volt outlet. Depths in the well are indicated by strips of adhesive tape wrapped around the cord at 10-foot intervals.

There are many kinds of conductivity cells, some good and some not so good, which can be used for well water measurements. Water Supply Paper 796-A of the United States Geological Survey describes several types, all of them easily made, which were used more or less

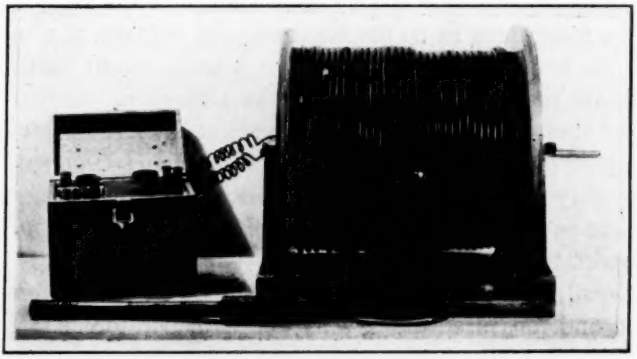

FIG. 1. Equipment used for conductivity measurements in deep wells. The hand-operated spool, holding 1,000 ft. of rubber covered wire, is connected through brush type contactors to measuring instrument on left. The conductivity cell rests horizontally in the foreground.

successfully for locating salt water leaks in a number of wells in Florida and Texas. These particular cells had copper electrodes, which apparently were good enough for the conditions there encountered, but ordinarily it would probably be better to use an orthodox or standard type of cell having platinum or gold electrodes. The one we use is a Leeds and Northrup industrial unit, mounted in a brass protecting case and fitted with a special tapered head which lessens the chance of losing the cell by getting it caught in some kind of an obstruction. It might be desirable also to have a weighted and tapered fitting attached to the bottom end, but in our work we have been able to get along with no modification of the cell other than the addition of the tapered head.

The connection between the cord from the cell and the cord wound on the spool is held in place by a special fitting which consists of a piece of hexagon-shaped brass, $\frac{5}{8}$ in. in diameter and 6 in. long. This fitting is bored longitudinally, thus making a tube which accommodates the cord and the two ends that are wound and taped together. The ends are threaded and split longitudinally, giving a compression type of clamp which can be screwed in place at each end. A similar but shorter type of compression fitting is used inside the tapered head on the conductivity cell, the idea being to carry the weight of the cell on the fitting and to relieve thereby a direct pull on the insulated connection.

Well Test Procedure

In testing a well to determine the source of salt water leakage it is essential that a pump be available and that the capacity of the pump be sufficient to move water throughout the entire depth of the well. Unless a test is made during or soon after pumping, conductance measurements are misleading and are likely to provide an altogether erroneous picture. When a well is standing idle, highly mineralized water tends to flow to the bottom, displacing water of better quality and creating a situation which, to say the least, is detrimental to a successful application of the conductivity method.

In making conductance studies it is helpful to have a log which shows the location of water bearing strata and where the casing is perforated. It is desirable also to know the length of the pump column, the diameter of the bowls, and the length of the suction. In fact, the more that can be found out about conditions in the well, the easier it is to explain and interpret the conductivity findings.

The actual test procedure is more or less flexible and to some extent is regulated by local conditions. In general, however, there are certain preliminaries and certain methods of operation which are applicable to all jobs of this kind. The first essential, of course, is that of suitable equipment. Our is perfectly satisfactory, but others might be just as good or perhaps even better. It is essential also to have a well pump of adequate capacity and, as noted above, to know the diameter of the bowls and the distance to the bottom of the suction. This information is important for two reasons: first, because the opening between the bowls and the casing might not be wide enough to accommodate the cell; and second, because the position of the suction frequently has some bearing on the movement of the water in the well and consequently on the conductivity readings.

As far as preliminaries are concerned, it is necessary, in our case at least, to have a 110-volt connection at or near the well. It is a good idea also to place the equipment on a bench or table and to have some kind of a pulley arrangement at the top of the casing to facilitate handling of the cord as it is fed into or withdrawn from the well. But the most important preliminary is that of sufficient pumping. Before a test is made, or at least before the results mean anything, a well should be pumped long enough and at a rate sufficient to induce flow throughout the entire depth and to bring in water from all of the contributing formations. Perhaps the best way of determining when to start is that of running chloride and hardness tests, or even conductivity tests, on samples from the pump discharge. When the results thereof remain constant for some little time, say an hour or two, it can be concluded that conditions in the well are no longer changing and that it is time to go ahead with the conductance survey.

When the test is started, the first step is to get the cell down the well. This is a fairly simple chore occasionally, but in most cases the clearance between the pump bowls and casing is such that it takes a little maneuvering to hit the opening and send the cell on its way. There are some wells in which it is impossible to make a conductivity survey, either because there is no opening at the top of the casing or because clearance at the bowls is less than the maximum diameter of the cell, which in our case is $1\frac{5}{8}$ in.

If obstructions are found, the program from then on will depend on how badly the water is needed and also on the past history of the well. If a well has produced good water, but the water has suddenly or gradually become saline, then conductivity measurements may prove very useful. Of course, if a well produced poor water from the time it was first drilled, the probability is that most of the contributing formations, or at least those which provide the bulk of the water, are the ones at fault. In that event nothing would be gained by making a conductivity test and by trying finally to seal off the salt water.

If a test is worth making, it is a small task to eliminate ordinary obstructions. If there is no other way of getting into the top of a well, it is always possible to set up a tripod and lift the pump far enough to get the cell inside the casing. In places where the pump bowls are too large, the only alternative, of course, is that of putting in a smaller pump. This would be wasted effort, however, if the small pump could not move the water in every part of the well.

In proceeding with a test in deep well pump installations, one should watch carefully for oil on the surface of the water. While the author has not determined exactly what effect a film of oil has on the electrodes, it is likely to be detrimental and should therefore be avoided. In our work we simply place the electrode end of the cell in a quart milk bottle full of water and lower the two together, using a separate string to handle the bottle. Finally, when the cell is submerged in the water and has passed the accumulated oil, it is drawn out of the bottle and the bottle in turn is removed from the well. In that way the electrodes are properly protected and there is no need to worry about the possible effect of the oil.

The next situation to guard against is that of operating the pump while the cell is going down the well. Although this might be possible in some instances, there is always a chance that the cell will be drawn against the suction and held there as long as the pump is running. It is quite likely, furthermore, that this effect will not be detected at the surface, which means that the cord will be let out in spite of no actual change in the position of the cell. If that happens, readings are perfectly constant and of absolutely no value in determining the source or sources of salt water contamination.

The safest method is that of stopping the pump while the cell is going down. If so desired, readings can then be taken at 10-foot intervals, or less if changes are indicated. When the bottom is reached, the pump is started again and the upward survey is not begun until samples from the discharge show a uniform hardness and chloride content. Then, with the pump operating, the cell is withdrawn slowly and readings taken at 10-foot or lesser intervals.

A second and perhaps equally satisfactory method for making these tests is as follows:

1. Start the pump and run it long enough to produce water of uniform quality.

2. Stop the pump and keep it shut down for the duration of the test.

3. Start conductance readings a half hour or so after stopping the pump.

Tests made in this way are of value in determining both the location of salt water leaks and the rate and extent to which the saline water replaces the fresh water.

One thing we have noticed in making the well tests is that it is

difficult at times to get a steady reading on the galvanometer. Possible causes of this condition are as follows:

1. Faulty or loose connections. The remedy here, naturally, is to make sure that all connections, including those in the cell itself, are properly made and tightened.

2. Polarization at the electrodes. This is due to a chemical reaction and the resulting evolution of a gas which collects on the electrodes and tends to form an insulating film. The remedy is to platinize the electrodes, which means plating them with a coating of platinum black. We have found it good practice to clean and platinize the electrodes before each series of tests or whenever the cell has not been in use for some little time.

3. Turbulent flow. Water entering a well from the various water bearing strata causes a turbulent flow or turbulent mixing effect which is reflected immediately by jumpy action of the galvanometer. Disturbances of this kind make accurate reading a little difficult, but ordinarily they are nothing to worry about. However, if the fluctuations become too severe, more satisfactory results might be obtained by repeating the test with the pump standing idle.

Interpretation of Conductivity Data

After a test is completed, the next step is that of tabulating the data and preparing a chart by plotting well depths against measured resistances or the corresponding conductivities. For practical purposes sufficient information can be obtained from the resistance readings, as variations therein indicate clearly the sources of salt water leaks and their effect on the quality of the water. However, if results are to be shown or expressed in terms of a common denominator, it is necessary to compute and record the corresponding conductivities. On that basis differences in equipment are eliminated and tests made in one locality can be compared with those made in another.

In computing conductivities from measured resistances, it is necessary to know the numerical value of the cell constant. This constant is dependent on the area of the electrodes and the distance between them and can be determined by measuring the resistance of a solution having a known conductivity. For well water surveys the constant should be fairly close to 0.10. At that value resistance readings usually fall within a 50- to 500-ohm range, which is usually the most satisfactory for precise reading of the slide wire scale.

If the cell constant is known, the conductivity of a solution may be computed by means of the following formula:

$$K = \frac{C}{R}$$

In the above K is the conductivity in reciprocal ohms, C the cell constant, and R the measured resistance in ohms. However, due to the number of decimal places ordinarily involved, it is not very convenient to express conductivities in terms of reciprocal ohms. It is better instead to use reciprocal megohms, which can be done simply by multiplying reciprocal ohms by one million. For example, if the measured resistance is 250 ohms and the cell constant is 0.10, the conductivity is .0004 reciprocal ohms or 400 reciprocal megohms.

For comparative purposes it is necessary to allow for temperature variations and also for the resistance of the cord. Temperature differences, unfortunately, have a marked effect, as conductance increases approximately 2 per cent per degree rise in temperature. It is convenient, therefore, to use a standard temperature of 18°C., either taking readings at that temperature or applying a correction factor of 2 per cent per degree Centigrade difference in temperature. For example, if the temperature of the well water being tested happened to be 15°C., the computed conductivity values would have to be increased 6 per cent in order to adjust them to the standard temperature of 18°C.

Resistance of the cord can be determined by measuring the resistance of a solution with and without the cord connected to the conductivity circuit. The difference between the two, amounting in our case to 13 ohms, should be deducted from the measured resistance before making the conductivity calculations. But when all is said and done, we are usually more interested in conditions at a given well than we are in knowing how those conditions compare with similar situations elsewhere. All we need ordinarily, therefore, is a chart showing depths and resistance readings, correcting neither for temperature variations nor for the resistance of the cord.

When the resistance goes up, total solids decrease, and when it goes down, total solids increase. It is a little difficult, though, to say exactly what values represent permissible limits for hardness and salinity. In a well survey what counts more than anything else is the range of the readings and the way they reveal variations in chemical quality. Sudden drops in resistance, for example,

mean a sudden inflow of salt water, and similarly, high resistances indicate strata where the water by comparison is softer and less saline.

If more exact information is required, the best plan is to test samples taken from a series of wells in the same general locality. On these run chloride, hardness, and total dissolved solids tests, and plot the results against the resistance or conductivity. In most cases only dissolved solids will mean anything, as hardness and chloride

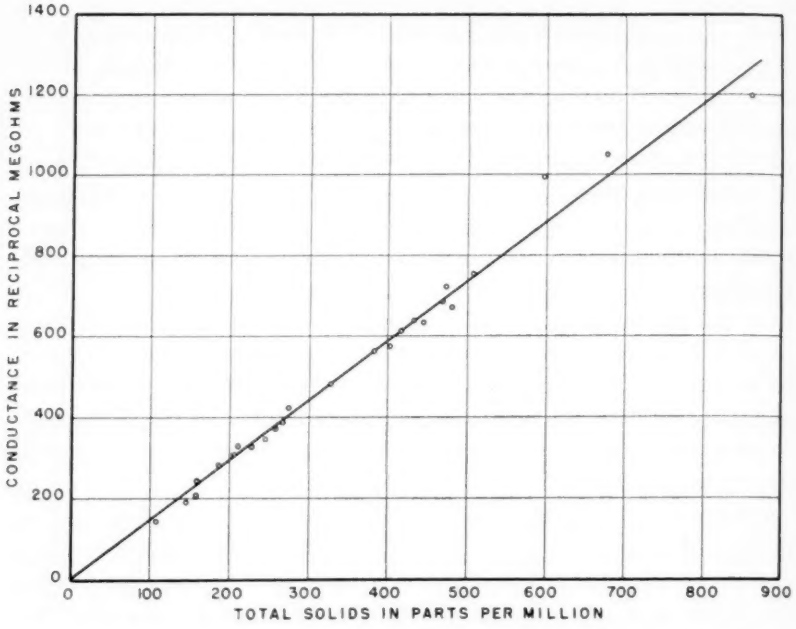

FIG. 2. Relation of conductance to total solids; total solids determined in some cases by evaporation and in others by computation from mineral analyses.

values are usually so scattered that it is hard to draw a satisfactory curve.

An example of the conductivity to total solids relationship is shown in Figure 2. Data for this chart were obtained by testing samples from a number of wells in southern California, determining conductance in the usual way and total solids by evaporation. But strangely enough, and contrary to what seems to be a general impression, we have found that samples from other sources give results

which fall on or close to the same line. Not only that, total solids on these additional samples, which incidentally were from widely scattered locations, were determined by computation from complete mineral analyses rather than by evaporation.

The chart is particularly applicable to total solids below 500 parts per million and the corresponding conductivity of 730 reciprocal megohms. Above these values the relation tends to stray a little, although it would be possible for practical purposes to dilute a sample enough to get a conductivity under 700 and to compute total solids accordingly. It seems possible, therefore, that this curve, or one similarly prepared, can be used for a fairly close, if not for an exact determination of total solids by the conductance method.

There is probably no sense in suggesting an arbitrary limit for conductivity. We have found from experience, however, that either the salinity or the hardness, or both, are likely to be objectionably high whenever the conductance exceeds 600 reciprocal megohms.

Referring now to the practical application of conductivity measurements, it should be of interest to describe the results of tests on three separate wells, all in different localities and all showing different characteristics with respect to hard or salt water leakage. For convenience these wells will be numbered 1, 2, and 3 and referred to accordingly.

Results at Well 1 are shown in Fig. 3. This particular well was tested because the hardness had increased more or less suddenly and we wanted to find out where the hard water was getting in and whether there would be any practical way of sealing off the contaminating strata. As shown by the graph, which is based on readings taken after pumping continuously for 16 hours, conductance values were constant from the initial water level at 73 ft. down to a depth of 94 ft. From that point down to 107 ft. the conductance increased gradually, but between 107 and 108 ft. it jumped suddenly from 520 to 1290 reciprocal megohms. From 108 ft. down to the bottom of the well at 150 ft. readings varied somewhat, but all values fell within what might be called a hard water range.

The interesting thing about this test is the way the changes in conductivity tied in with what was known about the location and depth of the water bearing strata. Of the two groups of perforations, the first is from 72 to 95 ft., which is the range where the conductance results showed water of satisfactory quality. The second group runs from 108 to 138 ft. and is obviously the source of

the hard water. This is reflected by the sudden increase in conductivity between 107 and 108 ft. and the consistently high results from that point down to the bottom of the well.

It is apparent that the hard water can be eliminated by plugging the well and sealing off the bottom stratum. This has not been done, however, because the well is used for standby purposes only and because the high hardness can be overcome by dilution from other sources.

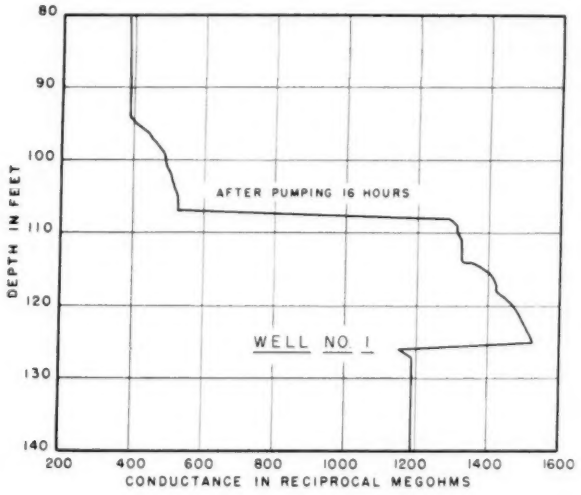

FIG. 3. Well 1; tests made after pumping continuously for 16 hr.

Tests at Well 2

Here is another example of a sudden increase in hardness. This well had been in service for a number of years when all at once something went wrong and consumers began complaining about hard water. On looking into the situation we found that the hardness had jumped to 490 p.p.m. as compared to a previous average of close to 160 p.p.m. We then made two conductance tests, one after pumping 21 hours and the second after pumping 97 hours. Both gave practically the same information, indicating each time that hard water was getting into the well between the depths of 150 and 250 ft.

As a result of the conductance study, it was decided that the best thing to do would be to plug the defective well and replace it with a

new well, some 200 ft. away. In drilling the new well, we tested samples from each of the water bearing formations and found conditions exactly the same as those indicated by the conductance findings, namely, hard water between 150 and 250 ft. and satisfactory water below 250 ft. Perforations were made accordingly and the supply since then has been perfectly satisfactory.

A somewhat different situation exists at Well 3. This is a new well, not yet in service, which was drilled within a few feet of two wells, both about 200 ft. deep, that had been abandoned because of salt water leakage. But the new well was not exactly a gamble, as it was preceded by a 3-inch test hole 500 ft. deep which showed that plenty of water, with a hardness of 50 p.p.m. or less, could be obtained from formations below 200 ft.

The depth of the new well is 545 ft. It was drilled with a rotary rig and was supposedly protected against salt water contamination by means of a cement seal around an outer casing which is 30 in. in diameter and 227 ft. deep. The inner casing, running the full depth of the well, is 16 in. in diameter and is perforated from 275 ft. all the way to the bottom.

When construction was finished and developing was started, plenty of water was found but it was of poor quality. Hardness and salinity were much too high and little or no improvement was obtained after pumping continuously for four or five days. To find out what was happening we made two conductance tests, one after the well had been standing idle and another after starting the pump and running it continuously for three days. The first test showed a conductivity at the top of 1,500 reciprocal megohms and no variation to speak of all the way from there down to the bottom of the well. In other words, the well was completely full of salt water. The second test, or the one after pumping, showed a material change. By referring to the graph in Fig. 5, it will be noted that soft water started coming in from depths below 290 ft., replacing the salt water and reducing the conductance at the pump suction from 1,500 to 595 reciprocal megohms.

Judging by the conductance results, there is no doubt but what the trouble is attributable to failure of the cement seal around the outer casing. Salt water from above the 200-foot level flows downward outside the 30-inch casing and enters the well through the first group of perforations at 275 feet. Water from lower depths is relatively soft, but when it gets up to 290 ft., leakage begins to take

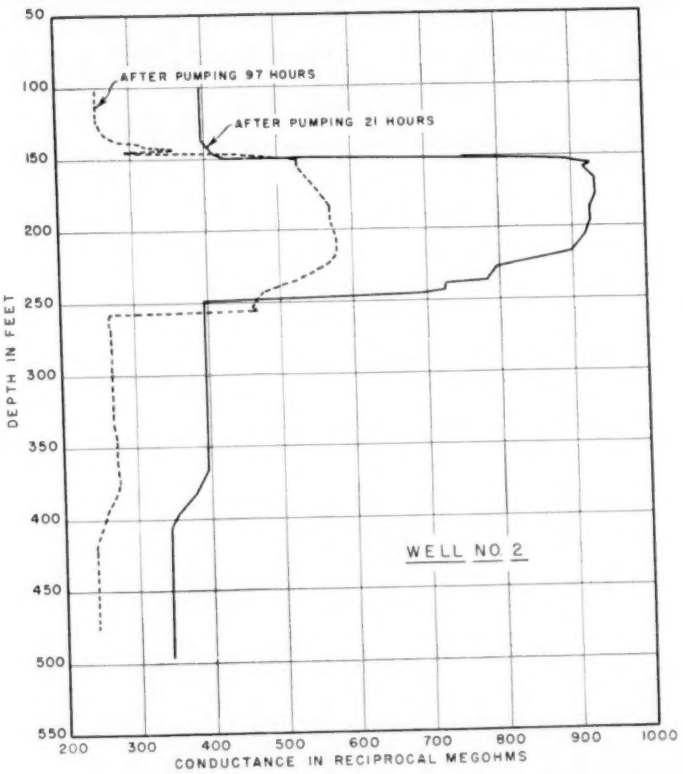

FIG. 4

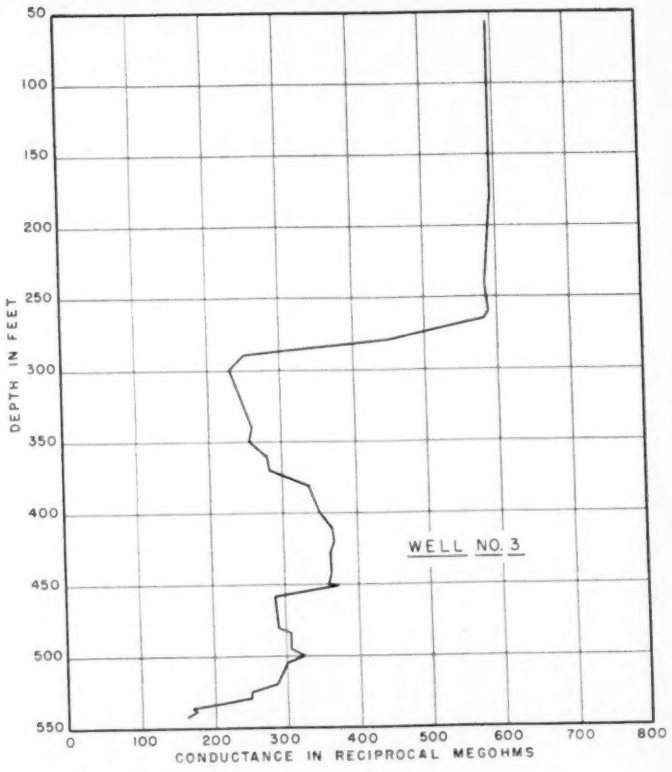

FIG. 5

FIG. 4. Well 2; first conductance test made after pumping 21 hr.; second test after pumping 97 hr.
FIG. 5. Well 3; tests made after pumping 72 hr.

effect and the conductance, as a result, jumps from 250 to 590 reciprocal megohms. In a practical sense this means that the well can be saved by finding some way to perfect the seal around the outer casing.

It might be well, in conclusion, to emphasize the fact that conductivity surveys are not always as simple as they may look. Some of our efforts, presumably because of unfavorable well or pumping conditions, have been disappointing to say the least. But with suitable equipment and careful manipulation there is probably no better method for the study *in situ* of well water quality.

Discussion by *H. C. Medbery*.* Without a background of practical experience in taking well conductivity measurements in the field, this dissertation must be made more in the form of a supplement to, rather than a discussion of, Mr. Brown's paper. Mr. Brown has given a good description of the solution of a difficult problem by the practical application of fundamental principles and it should be especially enlightening to those who may encounter similar problems.

For the benefit of those who may not have a clear understanding of conductivity measurements, a brief explanation of the basic principles may be of interest. Aqueous solutions such as we are discussing belong to the second class of conductors wherein the passage of electricity is always accompanied by the transport of matter. Both positive and negative ions move and therefore the specific conductance of any strong electrolyte is equal to the sum of the conductances of the separate ions, these conductances being calculated from the mobilities of the ions at the desired temperature and electrolyte concentration. These mobilities increase with rising temperature but due to inter-ionic effect decrease with increasing concentration. The conductivities of solutions are calculated usually by measuring the resistance of the solution at a known temperature, between two platinum electrodes coated with platinum black, with a wheatstone bridge. The resistance balance being made with either a galvanometer or head phones.

At our laboratory, we have the pipette type of conductivity cell and a Leeds and Northrup wheatstone bridge arrangement for the measurement of resistance. The current is furnished by four dry

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FIG. 5. Well 3; tests made after pumping 72 hr.

cells in series through a thousand-cycle hummer. We do not use a constant temperature bath but usually before testing we allow the sample to come to temperature equilibrium in the conductivity room, which is kept at about 20°C. The temperature of the sample is then read at the time of the test. To facilitate computations, a temperature-resistance curve is drawn for a sodium chloride solution of known conductivity, for computation convenience 100×10^{-5} reciprocal ohms. The conductivity of the sample is equal to 100×10^{-5} ohm^{-1} times resistance of sodium chloride at the same temperature as the sample divided by the resistance of the sample. To be sure that the cell constant does not change or in order to correct for any change, checks on the resistance of the standard sodium chloride solution are made at least once a week.

We find our conductivity measurements useful in making rough checks on the total dissolved mineral content of our various sources of water and as an aid in the detection of cross-connections and the origin of leaks. The ionic strength of a solution which is needed in calculating Langelier's calcium carbonate saturation index can be very closely approximated from the conductivity. We have found that 14.5 times the conductivity at 25°C. very closely approximates the ionic strength as computed from the mineral analysis.

No doubt, in the future conductivity measurements will be used more and more for checking mineral analyses. Gustafson and Behrman have published an article in the July analytical edition of Industrial and Engineering Chemistry, entitled, "Determination of Total Dissolved Solids in Water by Electrical Conductivity." In this article, they describe a method whereby the conductivity of a solution may be calculated from the various concentrations of the anions present. The method works fairly well because the equivalent conductances of sodium, calcium, and magnesium are fairly close together and potassium, which is somewhat higher, is usually present only in low concentrations. Thus, chloride salts of sodium, calcium, or magnesium all have about the same equivalent conductivity. The same similarity holds for the sulfates, bicarbonates, and nitrates.

The writer has made two sets of conductivity calculations from past mineral analyses, obtaining the following results. In the first set of 23 samples, the average calculated conductivities were about 2 per cent lower than the observed conductivities, the maximum

variations being 15 per cent lower for a sample with an observed conductivity of 1.88×10^{-5} ohm^{-1} to 10 per cent high for a sample whose observed conductivity was 95×10^{-5} ohm^{-1}. The majority of the samples had a conductivity of about 20×10^{-5} ohm^{-1} and the calculated value was usually within 3 per cent of the observed value. In the second series of 21 samples whose conductances ranged from 50 to 100 $\times 10^{-5}$ ohm^{-1}, the average deviation was 8.8 per cent high with a range of + 3.4 to +15 per cent.

These high results can be expected because Behrman's and Gustafson's values were obtained experimentally in more dilute solutions, about .001 Normal, while the conductivities of the second set were compared with conductivities measured on solutions containing from .004 to .008 gram equivalents of salts. The interionic effect reduces the mobility of the ions in the more concentrated solutions and thus to obtain better results, values which had been obtained from more concentrated solutions should have been used. Behrman and Gustafson made due allowance for this in their observed conductivities by diluting their samples until they contained about one milligram equivalent of salt and then multiplying by the dilution factor to obtain the conductivity of the original sample. Their calculated conductivities checked their observed values very closely and thus there must be much merit in this method.

The writer has made no conductivity versus total solid curves recently but he has drawn curves in the past for waters that had about the same proportion of salts and found that the points all fell very close to the curve. Theoretically, no curve would fit all waters unless about the same proportions of all ions are present in each water as the specific conductances per part per million vary for the different ions. However, the increase or decrease of a salt whose anion has an above-average specific conductivity per part per million may have a cation of below-average specific conductivity and they tend to compensate each other. Variations in proportions of sodium chloride, magnesium sulfate and calcium bicarbonate will have a small effect on the total solids-conductivity ratio while waters containing appreciable amounts of magnesium chloride or sodium sulfate as figured by the hypothetical salt combinations in a water would probably have a much different total solids-conductivity ratio. The writer does not, however, have experimental data on hand to back up this statement.

Discussion by *H. E. Bacon.* * Mr. Brown's description of the use of electrical conductivity methods for the rapid field analysis of well waters suggests the presentation of additional experimental data and references to the literature concerning the relation between specific conductivity and total dissolved solids. The conversion factor varies over a surprisingly small range even for samples of

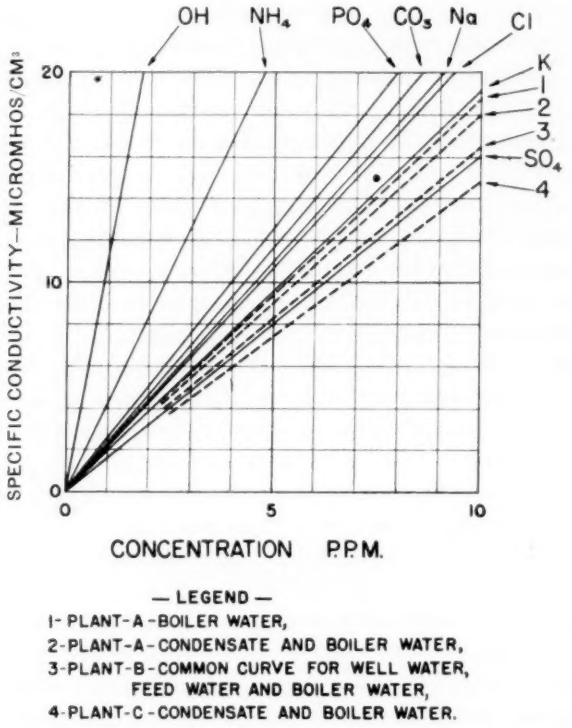

FIG. 6. Relation of Electrical Conductivity of Water to Concentration of Individual Ions and to Aggregate Dissolved Solids

such diversity as well waters (Mr. Brown's Fig. 2), surface waters (1, 2), and samples of boiler water, feedwater and condensed steam (3). The factor for converting reciprocal megohms or micromhos to total solids usually lies between 0.6 and 0.7.

Figure 6, submitted with this discussion, shows the relation between

* Principal Assistant to Sheppard T. Powell, Consulting Engineer, Baltimore.

conductivity and concentration for ions commonly found in boiler water and also experimental relations established at three power stations at widely scattered locations in the eastern United States. These experiments were carried out to verify the interpretation of conductimetric measurements of steam quality and the performance of steam purification equipment.

The accuracy of this method of estimating total solids is improved in special cases in which a limited number of ionic species strongly predominate. Examples are: (A) steam condensate contaminated by surface condenser leakage where the cooling medium is sea water or tide water, with sodium chloride predominating, (B) boiler water in which sodium is practically the only positive ion and the chemical treatment establishes sulfates, carbonates and phosphates as the major negative ions, and (C) condensed steam contaminated by boiler water solids. These special conditions, favorable to determining total solids by conductivity, may sometimes be created as a step in the analytical procedure: thus, in testing boiler water the preliminary neutralization of phenolphthalein alkalinity with sulfuric acid eliminates the highly conducting hydroxyl ion and brings the results in closer conformity to an empirical conversion factor.

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ABSTRACTS OF WATER WORKS LITERATURE

Key. 31: 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31:** 3: 481 (Mar. '39) indicates volume 31, number 3, page 481. Material enclosed in starred brackets, ★[□]★, is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British)*; *C. A.—Chemical Abstracts*; *P. H. E. A. Public Health EngineeringAbstracts*; *W. P. R.—Water Pollution Research (British)*; *I. M. —Institute of Metals (British)*.

BACTERIOLOGY

The Earlier Phases of the Bacterial Culture Cycle. C. E. A. Winslow and Harold H. Walker. Bact. Reviews. **3:** 147 (Dec. '39). From wide sources the authors have assembled most of the important facts constituting our present knowledge of what happens in a liquid culture of growing bacteria. The several *phases* of the bacterial culture cycle in chronological order are: (1) initial stationary, (2) early lag, (3) rest of lag, (4) early logarithmic increase, (5) rest of logarithmic increase, (6) negative acceleration, (7) maximum stationary population, (8) accelerating mortality, and (9) logarithmic mortality. From the work reported under the 119 references surveyed it is possible to recognize certain major groupings of these separate phases, with characteristics distinctive for a given major group. Thus, phases 1, 2 and 3 constitute the "Phase of Adjustment" in the culture cycle, while phases 2, 3 and 4 constitute the "Phase of Physiological Youth". Though undoubtedly the initial stationary phase represents the first step in every culture cycle of growth, the phase of adjustment probably is largely denoted by 5 characteristics associated with the early lag phase, namely: (1) low physiological activity, (2) relatively small cell size, (3) low multiplication rate, (4) rather high resistance to unfavorable conditions, and (5) relatively high electrophoretic mobility. The phase of physiological youth appears to embody all of the lag phase (the early part of which mainly constitutes the phase of adjustment just described) and the phase of early log increase, associated with which the following distinctive characteristics are manifested: (1) metabolic activity, (2) resistance to harmful environmental conditions, (3) morphological changes, (4) cell multiplication, and (5) resistance of young cultures to acid agglutination. ★[Recognition of the fact that in the culture cycle there exist: (1) major as well as minor phases, (2) that these functionally may over-lap or partially merge, (3) that "where the process is more rapid, the various stages are telescoped," and (4) that evidence is based largely on pure culture experi-

ments, makes one better appreciate the integrated complexity of these phenomena. Still greater must it be in the case of multiple mixed strains in laboratory test cultures of raw material, or of those in the natural environment.]★ Of fundamental biological significance is Henrici's observed analogy between the growth phases of a *unicellular bacterial population* and those of such *multicellular* organisms as *plant, animal* or *man*, as it clarifies considerably the conflict between pleomorphists and monomorphists. The organic *aggregate* of plant, animal or man constitutes the environment for the *individual* cells. In line with this view the authors say: "The study of the bacterial life cycle is . . . the bacteriological equivalent of the study of embryology, adolescence, maturity and senescence in the higher forms. Among the many important findings upon which rest the above principles are the following (necessarily condensed): cultures of different ages added to a new medium give widely different generation times; organisms in a given phase, transferred to the same medium under the same conditions, continue their activity in that phase; young cultures in the lag or early log phase are more sensitive to heat than at peak of the population curve, or at a late stage of the max. population phase; young cultures are more resistant to acid agglutination than old ones. Whether a given condition is unfavorable or not may very clearly depend upon peculiarities *inherent in the cells*. Injury to the inoculum such as chilling, partial disinfection, heat or ultra-violet rays, will prolong the lag phase. Alteration of environment by placing water in a sample bottle is usually sufficient to cause a temporary decrease in the mixed flora present. Variable concentrations of NaCl may result in steady increase, or steady decrease, or decrease followed by an increase of numbers of bacteria. ★[NaOH is often added to media to adjust the pH]★ Amount of inoculum vitally affects adjustment of the organisms to the environment. If too small, they may fail to develop. [★This suggests the possibility that, from this standpoint alone, the coliform index of water *sometimes* may not truly reflect its sanitary quality]★ Alterations in nutrient value of a culture medium constitute a factor in the early growth phases. ★[These alterations sometimes may well be incurred by the inoculum]★ The stationary phase is directly related to temp. Cells from a *young* primary culture behave in a secondary culture, for a time, differently than those derived from an *old* primary culture. Large active metabolic cells of the early culture cycle are much less resistant to various harmful chem. and phys. conditions. When colon bacilli cultures of various ages were exposed to 53°C. for 25 min., none in the early log phase (4 hrs.) survived, while all in the late log phase (7–13 hr.) did. ★[The water bacteriologist can study this article in detail with profit.]★—*Ralph E. Noble.*

Coliform Bacteria. LELAND W. PARR. Bact. Rev. **3**: 1 (Jun. '39). Viewing the article in perspective, the author first explains the origin and use of the terms "coliform", *B. coli*, "colon group", "coli-aerogenes", *Escherichia* and *Aerobacter*. Then he stresses the confusion which has resulted in thinking of the Friedländer group separate from other coliform bacteria. Next he traces the development of classification and characterization of the coliforms, their occurrence, significance, and pathology; the atypicals; variations within the

group; serology; and proposed classification allowing for recognition of the intergradation within the group. Conclusion brings out early encumberment of bacteriology with false species due to scarcity of comparative studies and to variations in single species. Now it appears that coliform bacteria must be thought of as a well-nigh ubiquitous group. Of these, that type will predominate in a given environment best adapted to living conditions therein. Recent revision of *Bergey's Manual* took cognizance of these principles to simplify coliform classification. "The coliform group is a large one made up of closely related, highly intergrading, and somewhat unstable bacteria which form a fairly wide gamut or *continuum* extending from the lactose-neg. paracolon forms at one extreme to the highly reactive *Aer. aerogenes* at the other. Standing with the paracolon forms next to *Salmonella*, one finds the Morgan bacillus. In about the same position, and leading to *Eberthella* and *Shigella*, are located the anaerogenous *Esch. coli*. Next to these varieties come the slow lactose-fermenting *Esch. coli* so likely to be manifested as 'unstable variants'. Completing one side of the picture, one finds the typical *Esch. coli* which bridge over to the *Aer. aerogenes* side by way of the 'intermediates'. Below *Aer. aerogenes* we find *Aer. cloacae* which appears to point toward the genus *Proteus*, and above all forms, but particularly above *Aer. aerogenes*, are located the Friedländer organisms". This concept is represented graphically. Finally the author expresses the view that our present understanding of the coliform group requires for its best expression the allocation of all these bacteria to 5 species within one genus. Assistance with opinions, unpublished data and pre-publication manuscripts from 52 outstanding scientists in this field is acknowledged by name. ★[In this 48-page review with 188 references, the author nicely embodies the more important facts and explanations essential to a clearer understanding of the coliform group. It should help orient present or projected work in the field.]★—*Ralph E. Noble.*

A Proposed Grouping of Aberrant Coliform Organisms. C. A. Stuart, Friend Lee Mickle and Earle K. Borman. J. Bact. **39:** 107 (Jan. '40). (Published in abstract only. Since the term "slow-lactose-fermenter" has been used to describe a number of different aberrant coliforms evidencing delayed or weak fermentation of lact., and since considerable difference of opinion has long existed regarding the sanitary (san.) significance (signif.) of these organisms, the use of a more exact terminology will promote uniformity of thought. Suggested terminology is based on morphological and biochem. studies of more than 10,000 coliform strains isolated from soil, milk, water, feces and other sources. Each aberrant coliform isolated in these studies could be assigned to one of four groups as follows: (1) *Micro-aerogenic coliforms* which produce gas slowly or in small amts. at 37°C. or 20°C. and which appear to have a san. signif. similar to that of comparable *Aerobacter*, intermediate or *Escherichia* strains showing typical lact. fermentation; (2) *Pseudo-micro-aerogenic coliforms* which have characteristics of the micro-aerogenic types at 37°C. but show normal lact. splitting activity at 20°C. and which probably have no san. signif.; (3) *Papillae-forming coliforms* which show the type of dissociation evidenced by *Bacterium coli-mutabile* but are not confined to the genus *Escherichia* and which are probably of more than

ordinary san. signif.; (4) *Anaerogenic coliforms* which produce acid but no gas from lact. and which probably are of more than ordinary san. signif. Discussion of the relationships of these groups to typical coliforms and "non-lactose-fermenting" coliforms is amplified by relevant serological observations. With respect to the bacteriological examination of water these studies indicate that no aberrant coliform giving a positive completed test in accordance with a strict interpretation of *Standard Methods* should be disregarded without a further study of its characteristics.—*Ralph E. Noble.*

Optimum Temperature for Differentiation of E. Coli from Other Coliform Bacteria. A. A. HAJNA AND C. A. PERRY. J. Bact. **38**: 275 (Sep. '39). Shellfish, water, sewage and other materials usually harbor a mixture of various coliform bacteria. To isolate *Esch. coli* from these substances, it is necessary to suppress the growth of other coliform types. Only practical method for purpose so far is incubation at 45°–46°C. where coliform types other than *Esch. coli* fail to grow and produce gas. *Esch. coli* strains usually grow and produce gas in a suitable medium properly used. Isolation in almost pure culture from positive tubes with eosin methylene blue plates is relatively simple, but plates streaked from tubes incubated at 44° or 37°C. frequently contain a mixture of spreading mucoid *Aer. aerogenes* or *Aer. cloacae* which are apt to have overgrown any *Esch. coli* present. Temp. between 45°–46°C. inhibit Citrobacter types and eliminate their confusion with *Esch. coli*. Authors studied unsatisfactory features of the Eijkman test and recommended reduction of carbohydrate to 0.3%, also addition of phosphates to neutralize acid formed. This modification was found superior to MacConkey's medium, apparently due to lower concentration of carbohydrate, presence of suitable buffers and use of a water-jacketed incubator. Properly controlled air incubator has been found preferable to a water-bath one since more strains of *Esch. coli* grow and produce gas. Organisms of the Aerobacter group are not usually found, to a large extent, in shellfish except under certain conditions. For this reason, temp. as low as 44°C. may be found practical even though not completely selective. Since, in their experience, an incubator temp. between 45.5° and 46°C. is easily obtained with a good water-jacketed incubator, and since *Esch. coli* is not suppressed to any appreciable extent in the authors' medium, whereas practically all strains of Citrobacter, *Aer. cloacae* and *Aer. aerogenes* are suppressed, they believe this temp. most satisfactory. —*Ralph E. Noble.*

Studies of the Toxicity of Basic Fuchsin for Certain Bacteria. CASSANDRA RITTER. Am. J. Pub. Health. **30**: 59 (Jan. '40). Dyes to be used for their selective bacteriostatic powers must have comparable toxicity; with inclusion in *Standard Methods* of fuchsin lact. broth, basic fuchsin dye must be added to list needing check for bacteriostatic power. Commercial basic fuchsin is usually a mixture of 2 or more homologs, homologs being tri-amino tri-phenyl-methanes. Homologs are: pararosanilin or Magenta O containing no methyl group; rosanilin or Magenta I, with 1 methyl group; Magenta II; and New Fuchsin or Magenta III. Pararosanilin most often is chief constituent of basic fuchsin dyes; commercial form very apt to be mixture of Magenta O,

I and II. In study 6 dyes tested for bacteriostatic titer against 10 strains of bacteria which might be found in water; among them strains of *Esch. coli* from feces, *Aer. aerogenes* from water, citrobacter, 2 slow lactose-fermenters, a streptococcus, and the aerobic spore-formers: *Bacillus aerosporus*, *Bacillus subtilus*, *Bacillus cereus*, and a cereus-like spore former. Pararosanilin was found least inhibitory of series and new fuchsin most inhibitory; addition of each new methyl group increasing the toxicity of the dye. Gram-neg. rod forms inhibited by comparatively low dilutions of dyes, ranging for pararosanilin from 1:5,000 to 1:25,000. Gram-pos. organisms inhibited by higher dilutions; inhibiting value for the streptococcus of pararosanilin is 1:140,000; spore-producing organisms least dye-tolerant. Concentration used in water analysis, 1:66,000, of pararosanilin or rosanilin would eliminate unwanted spore-forming organisms but not inhibit coliform group; pararosanilin dyes preferable for use, rosanilin, however, satisfactory.—*Martin E. Flentje.*

An Ecological Study of the Coliform Group. A. M. Griffin and C. A. Stuart. J. Bact. **39:** 90 (Jan. '40). (Published in abstract only.) Total of 6,577 coliform group organisms were isolated from milk, water, soil, grains, and feces, and classified according to their reactions in the "IMViC" differential media. Statistical analysis of the distribution indicates that Aerobacter and "intermediates" are normal inhabitants of water and soil but not of feces, while *Escherichia* are normal in feces but not in other sources. Strains exhibiting abnormally slow production of gas were of frequent occurrence in non-fecal materials. Results suggest that Aerobacter and "intermediate" sections of the coliform group are of questionable significance from sanitary point of view, and that speciation within group should not be too rigorous. —*Ralph E. Noble.*

Mucoid Dissociation in the Colon-Typhoid-Salmonella Group. H. R. Morgan and T. D. Beckwith. J. Infect. Dis. **65:** 113 (Sep.–Oct. '39). Dissociation of colon group of organisms with appearance of mucoid variant has been observed frequently. The limited work done indicated that mucoid type developed only if cultures were stored at 18°–25°C. and that alteration took place more frequently on Endo or eosin-methylene blue agar than upon a medium not containing lact. Authors studied possibilities of producing the mucoid form finding that a relatively low temp. of incubation (10–20°C) produces mucoid dissociant among members of colon-typhoid-salmonella group, and that continuation in mucoid form depends upon storage at a similar temp. Not all forms proceed to mucoid state with equal facility. Presence of a readily usable carbohydrate is essential to dissociation to the mucoid variant. Trend of dissociation of *Esch. coli* is smooth, or intermediate to mucoid to smooth. Mucoid *Esch. coli* is more resistant to desiccation than smooth or intermediate but there are no marked differences between these stages in tolerance to germicides. Mucoid *Esch. coli* are inagglutinable in antiserum from mucoid or non-mucoid organisms of the same strain. A preparation of the capsular material of the mucoid variant yields positive precipitates with the serum of immunized animals, and positive skin tests following intracutaneous injection. The different strains of *Esch. coli* produce capsular

complexes antigenically distinct. Characteristics of the capsular material, determined serologically, are independent of carbohydrate configuration from which it is formed. Included are 10 tables, 21 refs.—*Ralph E. Noble.*

The Effect of Certain Cultural Procedures on the Rate of Lactose Utilization by Slow Lactose-Fermenting Bacteria. J. O. MUNDT AND E. R. HITCHNER. J. Bact. **39:** 14 (Jan. '40). (Published in abstract only.) The progeny of slow lactose-fermenting strains often exhibit marked variations in rate of lact. utilization. Rapidly fermenting variants are readily obtained by training in lact. broth. Purpose of present investigation was to develop strains which would exhibit rapid lact. utilization without contact with same. Numerous daughter colonies from a slow lact.-fermenting culture (cult.), from a rapidly fermenting variant (48-hrs.) of this cult., and from a variant which failed to ferment lact. in 15 days were transferred to tubes of lact. broth, and observed for lact. utilization (acid production). Stock cults. of each of these daughter colonies were maintained on agar slants. From platings made from stock strain of a daughter cult. in each series which fermented the sugar within 2 days or less, a number of subcults. were made and carried through the procedure mentioned above. This procedure was followed through 25 subcults. The per cent of daughter strains which fermented lact. rapidly (within 2 days) varied from 12 to 60, with an ave. of approx. 30. A single exposure of the strain to lact. did not produce 100% of rapidly fermenting daughter strains. Altering composition of the medium by decreasing the organic N, cultivating in lact. solution with a mineral salts base, using massive inocula, altering the ratio of surface area to volume of test medium, and inoculating with cults obtained by single-cell isolation did not materially increase or retard the rate of lact. fermentation by these cults.—*Ralph E. Noble.*

Factors Limiting Bacterial Growth. VII. Respiration and Growth Properties of E. coli Surviving Sublethal Temperatures. A. D. HERSHEY. J. Bact. **38:** 563 (Nov. '39). When *Esch. coli* is subjected to heat, 3 effects may be recognized: decreased respiration in broth, prolonged latent period of subculture, and loss of viability. Correlation between these various effects is discussed. Regeneration of heat-inactivated respiratory function occurs at a constant rate characteristic of normal growth of the organisms, and is accompanied by physical growth. "Recovery from injury" appears, therefore, to consist of growth. Extended latent period of heated cells answers to the classical description of lag. In terms of cell physiology, however, it is not different from the latency of unheated bacteria, and consists of growth at constant rate. Equations describing growth at constant rate satisfactorily predict growth properties of heated bacteria, if quantitative changes in cell respiration are taken into account. Included are 2 tables, 3 figs., 14 refs. —*Ralph E. Noble.*

Preparation of Bacteriological Peptones. EINAR LEIFSON. J. Bact. **38:** 111 (Jul. '39). (*Published in abstract only.*) There is a need for bacteriological peptones made according to detailed published procedures. 115 peptones were made, dried and powdered. Substrates used included beef, beef heart,

beef spleen, beef lung, pork, hog stomach, fish, casein, wheat gluten and soybean flour. Enzymes used, except papain, were prepared in the lab. and included pepsin, pancreatin, papain, as well as serial digestions with combinations of these. Work is in progress with additional substrates. These peptones, and a number of commercial ones, have been tested extensively for diphtheria-toxin production, growth-promoting properties for some 50 selected strains of bacteria, and suitability for various biochem. tests such as indol, M.R., V.P., double-zone formation by streptococci in blood agar, pigment and gas production. The data indicate that peptones as good as, or better than, the present commercial products may be made cheaply and easily. Many peptones produce high concentrations of diphtheria toxin. Author invites correspondence and would welcome cooperation in making special tests on peptones.—*Ralph E. Noble.*

Dye Modification of Bismuth-Sulfite Media. (*Published in abstract only.*) H. C. Mason. J. Bact. **36:** 314 (Sep. '38). Problem was to determine action of dyes and certain other substances on the bismuth-sulfite medium of Blair and Wilson in order to provide supplementary procedures to those now in use for differentiation of certain Gram-neg. enteric bacilli. Media used: (1) Wilson and Blair's; (2) Tabet's modification of Wilson and Blair's; (3) bismuth sulfite (Difco); and (4) selenite enrichment. Dyes and other substances added to the first three, in concentrations ranging from 0.003 to 0.15% were: acid acriflavine, neutral acriflavine, acid fuchsin, basic fuchsin, fuchsin, brilliant cresol blue, chrysoidin, Congo red, fluorescein, indigo carmine, malachite green, methylene blue, oxyquinoline sulfate, phenol red, phosphomolybdic acid, pyronin, quinaldine red, scarlet red, sodium hippurate, tannic acid, thionin and trypan blue. A large number of enteric bacilli chosen from a variety of genera and a few other kinds of bacteria were used as test organisms. Broth and agar-slant cultures from 18–24 hr. old of freshly isolated and old lab. strains were employed. Addition of dyes produced distinctive colonies for typhoid and paratyphoid strains. Most favorable reaction was secured by adding phosphomolybdic acid in concentration of 0.003–0.005% to the bismuth-sulfite medium. Addition of such substances as tannic acid, sodium hippurate and phenol red can be adjusted to allow growth of dysentery bacilli to take place, but this will also permit development of other organisms.—*Ralph E. Noble.*

Light as a Factor in the Production of Pigment by Certain Bacteria. J. A. Baker. J. Bact. **35:** 625 ('38). One of the best ways to encourage pigment production is to incubate culture in the usual way till it has grown and then leave it on the bench exposed to diffuse daylight. Author studied some conditions governing effect of light on pigment production. Work carried out with a strain of a saprophytic acid-fast bacillus that formed colorless growth in the dark and rosy pink in the light. Fully developed cultures on glycerol agar were exposed to different types of light for varying times, and then kept in the dark and examined for pigmentation. Exposure to sunlight for 15 min., to a 100-watt Mazda incandescent lamp 2′ distant for 30 min., and to a mercury

vapor lamp 3″ distant for 1 min. all led to development of maximum coloration within 48 hr. Further experiments showed that color developed best if cultures were irradiated at 37°C. and incubated afterwards at 24–37°C. If the cultures were irradiated at 24°C., and kept subsequently at 24° or 37°C., coloration was not so good. Cultures kept at 4°C. after irradiation failed to develop any pigment at all. Formation of pigment appeared to be an active metabolic phenomenon since: (1) cultures killed at 60°C. for 30 min. did not develop pigment; (2) cultures exposed to light for so long that they were killed did not develop pigment; (3) pigment readily soluble in alcohol, but exposure to light of an alcoholic extract of an unpigmented culture did not lead to formation of pigment.—*W. P. R.*

The Coli Aerogenes Index of Pollution Used in The Bacteriological Analysis of Water. RAO SAHIB, T. N. S. RAGHAVACHARI AND P. V. SEETHARAMA IYER. Ind. Jour. Med. Res. **26:** 867 (Apr. '39). It is desirable in water analysis to differentiate between coli and aerogenes if only to correlate finding with other data of chem. analysis and survey at source of supply. It has been established that while coliform rapidly destroyed, on exposure to Indian sunlight, *B. aerogenes* and *B. cloacae* had greater powers of resistance, especially the latter. In the study reported on, differentiation technique of Wilson was applied to examination of 12 water samples from Madras. The procedure was as follows: (1) each water sample was inoculated into MacConkey's bile-salt-lactose-neutral-red broth in one 50 c.c., five 10 c.c., five 1 c.c. and five 0.1 c.c. quantities; (2) after 24 hr. incubation at 37°C one tube showing acid and gas from each dilution was plated out on MacConkey's bile-salt-neutral-red agar and kept 24 hrs. at 37°C, 6 colonies being picked off for confirmation on MacConkey's broth; (3) all positive strains were put through tests—methyl-red, V.P., citrate-utilization, indole, ability to produce acid and gas in MacConkey's broth at a uniform temp. of 44°C accurately maintained in a water bath; (4) at end of 24 hr. at 37°C every tube showing acid and gas in original 37°C enrichment series was inoculated first into MacConkey's broth tube and placed immediately in water bath at 44°C for 24 hrs. and then into Koser's citrate broth tube for 48 hrs. at 37°C (Wilson's method); (5) all tubes in (4) were plated out on agar, 2 colonies being picked off and put back into broth. In the original work it was found that the Wilson test was superior to all others in picking out a high proportion of fecal coli strains with rapidity. In this study it was found that 60 to 70% of aerogenes-like organisms isolated from water possessed ability to produce acid and gas in 24 to 48 hrs. in MacConkey's broth at 44°C, this data contrary to Wilson's results, and indicating Wilson method for water analysis may not be applicable to tropical waters.—*Martin E. Flentje.*

Sodium Lauryl Sulfate Broth for Coliform Detection. E. R. HUPP. J. Bact. **38:** 596 (Nov. '39). (*Published in abstract only.*) The use of 0.02% sodium lauryl sulfate in standard lact. broth for the enrichment of water samples has been suggested (JOUR. A. W. W. A. **30:** 979 (1938)) to prevent growth of spore-forming gas formers without affecting the development of

coliform organisms. This is desirable in order to obtain final results earlier and reduce lab. work. In one series, 118 positive presumptives were obtained in standard lact. broth, none of which confirmed. In lauryl broth, there were no positive enrichments. One series produced 77 coliforms in standard lact. broth and 79 in lauryl broth. Another series produced 134 in standard and 124 in lauryl. The last series produced substantially the same results obtained with brilliant green.—*Ralph E. Noble.*

Growth and Survival of V. Cholerae in Water. W. D. B. Read, Gurkirpal Singh and S. Bose. Wtr. and Wtr. Eng. (Br.) **41:** 538 (Nov. '39) (*from* Indian J. Med. Res.). Sea salt and organic matter are required for multiplication and survival of cholera vibrios in artificially prepared water. Salt required varies inversely with organic content. Multiplication and survival conditions are similar to each other. Presence of other organisms in comparatively equal inocula, except the inagglutinable vibrio, is not inimical to multiplication of the agglutinable one. Latter can survive up to 3 weeks or longer in presence of former. Salt and organic requirements for multiplication in natural and artificial waters are practically the same. A general relationship was found between ave. total solids content of natural waters in the Calcutta area and prevalence of cholera. *[It seems important that these workers found that in the absence of salt, multiplication did not occur in any peptone concentration, nor did survival reach 24 hrs. in any case.]*—*Ralph E. Noble.*

Inhibiting Spore-Formers in the Examination of Water Supplies. John W. M. Krasauskas. Md.-Del. W. and Sew. Assn. **13:** 55 ('39). Review is given of bacteriological methods developed to eliminate interfering organisms in *Standard Methods* lact. broth. Test results reported involve comparison of standard lact. broth and this media plus added alkyl sulfate (available in "Drene" shampoo containing sodium lauryl sulfate) to amount of 1 c.c. to 1 liter of broth. Lact. broth alone was found more productive for coliforms but lact. "Drene" yielded least number false tests.—*Martin E. Flentje.*

The Determination of the Quality of Nutrient Media by Means of the Bacteriological Photoelectric Nephelometer. E. I. Demikhovskiĭ. Z. Microbiol. Epidemiol. Immunitätsforsch. (U.S.S.R.) **19:** 123 (in English 128) ('37). Intensity of growth is normally used to determine quality of nutrient medium, but it is more accurate to judge media in terms of "generation time." Rate of generation time is measured by determination of increased turbidity of cultures by means of photoelectric nephelometer constructed in an incubator. In expts. on *Esch. coli*, cultured on media prepared from placenta at pH 6.6-7.7, identical values of increasing turbidity were obtained; thus *Esch. coli* multiplies with equal rapidity at all pH values within above range. When meat-infusion peptone broth, prepared from decayed placenta, a similar medium from fresh placenta and Hottinger's broth, also from fresh placenta, were used at pH 7.4, latter was found to be best medium for growth of given strain of *Esch. coli*.—*C. A.*

A Modified Fermentation Tube. PHILIP B. COWLES. J. Bact. **38**: 677 (Dec. '39). Author describes a type of fermentation tube designed to replace, for some purposes, the usual form in which an inverted vial collects the gas evolved. It is made of pyrex glass tubing of 6 mm. outside diam. and 1 mm. wall thickness. Dimensions are such as to fit a standard 100 ml. water sample bottle or a 25 mm. culture tube. Within limits, any size of glass tubing can be used and dimensions varied to suit. Both ends are open, upper extending somewhat above the upper bend, lower end terminating above the lower bend. Great advantage is that tube fills when dropped into liquid, or, if in an empty vessel, it fills when fluid is poured in. Once filled, both arms of the inverted "U" serve as traps for gas evolved. With such a culture system bottle volume need be little larger than that of water sample. There is no danger of admitting air to the gas tube either through tipping or drying. Where some time must elapse before samples reach the lab., period may be utilized for growth and gas production. ★[Following the above idea, this type fermentation tube has been made from stock tubing in the Chicago Health Dept. water lab. Tube is placed in a wide-mouth 4-oz. ground glass stoppered bottle with 20.0 ml. quintuple lact. broth before sterilization. After filling to shoulder with 100.0 ml. water sample at point of collection and returning to lab., glass stopper is replaced with pre-sterilized cotton plug and sample incubated. It works.]★—*Ralph E. Noble.*

The Effect of Alcohol in Disinfection of the Hands. F. NEUFELD AND O. SCHIEMANN. Ztschr. f. Hyg. u. Infektionskr. **121**: 312 ('38). Preliminary observations showed that *Esch. coli* was killed almost immediately when a few drops of a watery suspension were added to 80% or 96% alcohol, while spores of *B. subtilis* or *B. mesentericus* were still alive after 3 days. Observations were then made on action of alcohol on fingers infected with a mixture of *Esch. coli* and sporing bacilli. By plating the washings it was found that all coliform organisms had been killed, but not sporing organisms. Alcohol was not superior to soap and water as a pure cleansing agent; nor did it appear to fix organisms on the skin, as has been held by certain previous workers. Its action appeared to be almost exclusively that of a disinfectant. Fact has long been established that alcohol acts only in the presence of water. Present authors confirm this statement, and show that while 80% alcohol will kill vegetative organisms on the dry hands almost at once, 96% alcohol will kill only if hands have been previously moistened.—*B. H.*

Bergey's Manual of Determinative Bacteriology. A Key for the Identification of Organisms of the Class Schizomycetes. DAVID H. BERGEY, (formerly of Univ. of Penna.), ROBERT S. BREED, (N. Y. State Exp. Sta., Cornell Univ.), E. G. D. MURRAY, (McGill Univ.), AND A. PARKER HITCHENS, (Univ. of Penna.). Fifth Edition.—pp. xi + 1032. '39. Balt.: Williams & Wilkins. $10.00. In the five years since the fourth edition of Bergey's well-known *Manual* was published science of bacteriology has made several notable ad-

vances, fresh organisms have been discovered and considerable rearrangement of those already known has been necessary. No classification is likely to meet approval of all bacteriologists; subject is too vast for one person or group of workers to comprehend or even to visualize, and those who have studied mainly morphology, or so-called life-cycles, and variation, or others who have paid a special attention to antigenic analysis will naturally tend to regard systems of classification proposed hitherto as at least incomplete, if not erroneous and misleading. The fourth edition was a work of 664 pp., the present issue 1,032, an increase of over 50%. Chairman of the original board, Prof. David H. Bergey, has died since the last edition was published; Prof. Robert S. Breed of Cornell Univ. has succeeded him as chairman, and Prof. Parker Hitchens of the Univ. of Penna. has been elected on the board of editor-trustees. First edition, in '23, contained descriptions of 832 species and references to 1,577 descriptions; this new issue describes 1,335 species and 5,600 references. New features are chapters on an "Historical Survey of Classifications," of interest not only to the historian but also to any bacteriologist who is anxious to get a bird's-eye view of how the subject has progressed; also an important chapter on "How Bacteria Are Named and Identified"; the section on Rules of Nomenclature has been extended and amplified. Many subjects have been rearranged and more intensive study of the past five years has necessitated removal of organisms from one group to another, as well as enlargement of groups by the need for finding place fof fresh discoveries. The Order of Eubacteriales has quadrupled its families, in place of the 3—Nitrobacteriaceae, Bacteriaceae and Bacillaceae—there are in this edition 12. Among members of various genera several are included whose relationships at present are not clear; these will call for further rearrangement as the result of future study clears up difficulties. 9 new generic names are used, and 3 of them—*Caulobacter, Pasteuria* and *Blastocaulis*—are relegated to a newly recognized Order *Caulobacteriales,* non-filamentous bacteria growing characteristically on stalks. In appendices to genera are placed temporarily some which have been recently found or are poorly described, i.e. organisms of which we have at present fragmentary knowledge only. It will be observed with satisfaction that few new binomials have been formed and the habit of using trinomials has been resisted absolutely. Occasionally, and wisely, the current name of a species has been preferred to one which would, by laws of strict priority, be used, the latter for convenience of reference being given as a synonym. Since the authors have takenthe trouble of consulting original sources wherever possible, confirming the accuracy of references, and checking the descriptions with the original accounts, some idea of the colossal amount of tiring, irksome, but necessary labor may be imagined, but without it the finished product would be misleading, and of little worth. As it is, it stands as a monument of determinative bacteriology.—*B. H.*

BOILER FEEDWATER

Eliminating Nightmares of Water Conditioning. R. E. Hall, E. P. Partridge, and T. H. Daugherty. J. Inst. Fuel **13:** 27 ('39). General account is given of methods for prevention or treatment of mechanical failures fre-

quently encountered in operation of steam boilers. Necessary to maintain a proper ratio of chloride as well as of sulfate to alkalinity in feed water to avoid cracking in boiler tubes. Certain tannins and lignin derivatives are effective inhibitors of intergranular attack. Deposits on screens placed in steam lines may be mainly water-soluble and may be derived from solids in boiler feed water carried over in fog in steam; breakdowns due to this can be avoided by improved boiler design to give sufficient steam-carrying capacity between drums of boiler. Interior surfaces of new boilers must be cleansed before raising steam; in operation of boiling-out, water must be alkaline. Sodium lignin sulfonate or a dispersive tannin is recommended as a safeguard against caustic embrittlement; time is saved by using powerful detergents containing for example 40% sodium hexametaphosphate and an alkaline constituent. Formation of scale in condenser tubes may be prevented by "threshold treatment"; addition of 2 p.p.m. of sodium hexametaphosphate to feed-water will prevent deposition of calcium carbonate scale. Formation of sodium aluminium silicate scale is due to rapid localized evaporation of boiler water to dryness, repeated so frequently that deposits cannot re-dissolve. This trouble can be counter-acted by decreasing transfer of heat over affected area by lagging and by treating feed water with CO_2 to lower its pH value prior to softening it by zeolites. Deposits occur on strainers or valves following de-superheaters; such deposition can be prevented either by using pure water in the de-superheater or by preventing water from evaporating to dryness in it.—*W. P. R.*

Boiling. Heat Transfer in Natural Convection Evaporators. G. A. AKIN AND W. H. MCADAMS. Ind. Eng. Chem. **31:** 487 (Apr. '39). With distilled water boiling at atmospheric pressure on horizontal nickel- or chromium-plated tubes, max. flux was approx. the same (350,000 B.t.u. per hr. per sq. ft.) in single- or 60-tube apparatus. City water boiling on a scaled tube gave approx. same max. flux but temp. difference was increased from 45° to 80°. Decrease in flux due to vacuum not so great in high flux ranges studied as that reported by others who used low flux. Data are also reported on 3 paraffin alcohols.—*Selma Gottlieb.*

Plain Talk on Embrittlement. C. H. FELLOWS. Power **82:** 553 (Oct. '38). A concentrated review of the present status on question of embrittlement is expressed in a manner understandable to non-chemists. Local concentration of sodium hydroxide in presence of silica is cause of embrittlement. Old A.S.M.E. sulfate-carbonate ratios are not final solution to problem—particularly for boilers operating at high pressures such as 1400 lb. Use of lignins (below 550 lb.), sodium chloride, and R_2O_3 are now being studied under actual operating conditions. Operators suspecting water of causing caustic embrittlement should have it tested and consult a specialist before attempting to "dope" the boilers with possible cures.—*T. E. Larson.*

Recirculation of Boiler Waters to Hot-Process Softeners. JOHN J. MAGUIRE AND W. J. TOMLINSON. Combustion. **11:** 3: 26 (Sep. '39). Further advantages to be gained from boiler water recirculation (cf. Abst. Jour. A.W.W.A.

31: 1623 (Sep. '39)) are discussed. Methods include return to hot-process softeners (phosphate or lime-soda), to cold-process softening (batch or continuous) under specific conditions, and to coagulation tanks for alkalinity adjustment. Generalities are avoided since individual application of recirculation is of necessity based on particular conditions encountered. Blowdown equipment, control and most suitable tie-in to system varies in different cases and must be estimated on basis of operating conditions and equipment available.—*T. E. Larson.*

Use and Application of Chemicals for Preventing Deposit in Pipe Lines. R. M. STIMMEL ET AL. Am. Ry. Eng. Assn. Bull. **41:** 414: 240 (Nov. '39). The precipitation of calcium carbonate in water lines as well as heaters, cooling coils, etc., may be prevented by the use of tannins or molecularly dehydrated phosphates such as sodium hexametaphosphate. The optimum dose of tannins will vary from 1 lb. of tannin to from 4,000 to 15,000 gal. of water. Good results have been obtained with hexametaphosphate using a treatment of 1 lb. to 60,000 gal. and in some cases as high as 120,000 gal. of water.—*R. C. Bardwell.*

Complex Silicate Scales in High-Pressure Boilers. Their Occurrence and Correction. SHEPPARD T. POWELL, LEWIS V. CARPENTER AND JOHN J. COATES. Combustion **11:** 2: 18 ('39). In high-pressure boilers complex NaAl silicates cause scale even when the feed water contains a small amount of Si. Si can be removed from the water by treatment with $Fe_2(SO_4)_3H_2SO_4$ solution at a pH of 3.5 to 4.5 followed by alkalinization to pH greater than 7.5. Waters containing 2 to 3 p.p.m. of soluble Si when treated with concentrations of $Fe_2(SO_4)_3$ of 50 p.p.m. Fe resulted in a residual Si content of 0.5 p.p.m. The silicate scale resembles in structure analcite found in certain volcanic formations. Typical plant installations are described.—*C. A.*

Cause of and Remedy for Pitting and Corrosion of Locomotive Tubes and Sheets with Special Reference to Status of Embrittlement. R. E. COUGHLAN ET AL. Am. Ry. Eng. Assn. Bull. **41:** 414: 214 (Nov. '39). "Embrittlement" or "intercrystalline corrosion," in riveted seams of locomotive boilers has been encountered and definitely identified on a number of American railroads. Intercrystalline cracking not due to water conditions alone but to a combination of factors that simultaneously create following conditions: (1) an embrittling water, (2) high cold working or applied stress in the metal; (3) slow leakage and concentration in the riveted seam, and (4) contact of concentrated solution with the stressed metal. Experience with locomotives indicates that neither Na_2SO_4 nor a combination of Na_2SO_4 and NaCl afford protection. Use of lignin containing materials such as sulfite liquor, and tannins such as quebracho under controlled conditions, has materially reduced cracking. "Embrittlement detectors" developed by the Bureau of Mines have been applied to locomotives in different sections of the country for checking embrittling characteristics of various water conditions and corrective treatment is being applied where warranted.—*R. C. Bardwell.*

Types of Tannins Used in Water Treatment. R. M. STIMMEL ET AL. Bul. Am. Ry. Eng. Assn. **40**: 407: 220 (Dec. '38). Chestnut and oak wood extracts of the depside tannins and hemlock extract, quebracho, and cutch of the phlobatannins have been used extensively in water treatment to: (1) reduce incrustation in boiler feedwater lines, (2) inhibit pitting due to oxygen, (3) modify deposits on boiler sheets and tubes, and (4) prevent intercrystalline corrosion or so-called "caustic embrittlement." Concentrated waste sulfite liquor produced during the manufacture of pulp by sulfite process is also used for same purposes but this does not contain tannin although liqueous matter present frequently gives similar reactions in water treatment. Because of individuality and varying tannin content of various extracts, tannins should not be used indiscriminately.—*R. C. Bardwell.*

Conditioning Water for Vapor Heating Boilers on Diesel Powered Trains. RAY MCBRIAN ET AL. Am. Ry. Eng. Assn. Bull. **41**: 414: 219 (Nov. '39). Vapor boilers, used for heating diesel-powered trains, require water conditioning to prevent scale formation, pitting and corrosion. Steam at 200 lb. pressure is produced rapidly in continuous coils of steel tubing several hundred ft. long with no satisfactory means for mechanical cleaning. Where proprietary compounds are used for water conditioning, frequent blowdown is necessary and coils must be cleaned every 30 days with passive acid. Condensate, suitably conditioned by anti-corrosion treatment, is satisfactory but expensive. Exchange filters consisting of 2 layers of processed synthetic resins, for removal of both the cations and anions in dissolved solids, are being used successfully at an operating cost of 34¢ for H_2SO_4, NaOH, and wash water, to condition a water containing 395 p.p.m. dissolved solids. Where raw water is low in Cl and SO_4, use of H-Zeolite in combination with Na-Zeolite affords another means of securing a feed water low in dissolved solids.—*R. C. Bardwell.*

Boiler Feedwater Treatment, 1930-1940. FREDRICK G. STRAUB. Power Plant Eng. **44**: 1: 65 (Jan. '40). Review is given on new methods for chem. control of boiler feedwater. Cold process softening rates have been increased by means of precipitator and accelerator equipment. Zeolite softening has been altered by introduction of non-siliceous zeolites which can be operated on either a hydrogen or sodium cycle with resulting advantage of lower total solids and no silica pickup on softening. Metaphosphate in secondary treatment is being used to advantage. Chem. treatment with deaeration is employed in complete removal of dissolved oxygen for corrosion prevention.—*T. E. Larson.*

Treating Boiler Feedwater Chemically. C. W. BUFFINGTON. Proc. of the Master Boiler Makers' Assn. p. 38 ('39). Maintenance of an excess alkalinity over the hardness in actual boiler water of at least 15% of total dissolved solids, in addition to proper attention being given operation and maintenance of locomotives, is recommended. The lime-soda, wayside, zeolite, and boiler compound methods are discussed as well as blowdowns, boiler washing, and embrittlement.—*R. C. Bardwell.*

Water Treatment on the Alton Railroad. R. W. SENIFF. Proc. of the Master Boiler Makers' Assn. p. 42. ('39). The Alton R. R. operating between Chicago, St. Louis, and Kansas City, obtains water for its 169 locomotives operating from 5 to 10 million engine-miles per yr., from 51 supplies which vary in total hardness from about 110 to 800 p.p.m. with a non-carbonate hardness from 0 to 390 p.p.m. Use of water without treatment caused serious scale and corrosion with frequent delays to trains. Supervised treatment initiated in '22 by adding soda ash to all supplies in amounts necessary to neutralize non-carbonate hardness. This treatment reduced scale troubles and delays from leaky boilers but corrosion became worse. In '27 soda-ash treatment was increased to maintain an excess amounting to 30% of dissolved solids. Treatment resulted in a remarkable decrease in corrosion. Foaming was also decreased rather than increased by this excess treatment. Supervised blowdown schedules remove the sludge and sediment and maintain clean boilers. Seniff strongly recommends this method of treatment if carried out under supervision of properly trained chemists.—*R. C. Bardwell.*

Water Treatment on the Canadian National Railways. M. V. MILTON. Proc. of the Master Boiler Makers' Assn. p. 53 ('39). Water treatment on the Canadian National Ry. is carried out by applying chemicals in the form of boiler compound to tender tanks just before leaving the terminal, amount being based on chem. check tests made by the boiler foreman. Proper concentration is obtained by blowdowns and dissolved solids are checked at terminals by the boiler foreman. Clean boilers are maintained by a carefully regulated system of pre-cooling before emptying and washing which method is described in detail.—*R. C. Bardwell.*

Water Treatment Results on the Pere Marquette Railway. ARTHUR D. O'NEIL. Proc. Master Boiler Makers' Assn. p. 58 ('39). 9 treating plants located at principal stations soften 46% of water supplied the 214 locomotives on the Pere Marquette Ry. Scaling matter in balance of the supply is kept at minimum by addition of soda ash and tannins direct to locomotive tenders at 28 other points, under supervision and check by company chemist. Systematic blowdowns are maintained by check of dissolved solids from boiler water samples with a conductivity test set called a "Nalcometer". Boiler conditions have been considerably improved by the treatment, and washout periods have been extended to the full 30-day Federal allowance.—*R. C. Bardwell.*

Water Conditioning Improvements on the Louisville & Nashville Railroad. M. MANLEY. Proc. of the Master Boiler Makers' Assn. p. 61 ('39). Automatic blowdown which discharges only when the throttle is open is practiced in road service with sufficient manual blowing at terminals to maintain the dissolved solids below the allowable concentrations to prevent foaming. Pre-cooled washing of boilers is also recommended.—*R. C. Bardwell.*

Water Treatment on the Buenos Aires Southern-Western Railways. E. CRAPPER. Proc. Master Boiler Makers' Assn. p. 63 ('39). After a test installation at Trenque in '32, on a 35° hardness water with 15° permanent,

produced very good results in eliminating boiler troubles, the Buenos Aires Southern-Western Ry. decided to arrange for complete softening of their locomotive water supplies with zeolite plants. This involved 180 plants. Installations began in '36 and 60 plants were in service by '39. Results have not been so satisfactory. Scale has been eliminated and foaming reduced but pitting and corrosion have caused as much damage to boilers and as great repair expense as formerly experienced with scale troubles. Wastage of copper ferrules and brass washout plugs had not previously occurred. Vendors of the plants have recommended supplemental treatment with quebracho. —*R. C. Bardwell.*

Treating Boiler Feed Water Chemically, Washing and Blowing Boilers to Reduce Concentration, and Suggestions to Improve Boiler Conditions. F. YOCHEM. Proc. Master Boiler Makers' Assn. p. 67 ('39). Chem. treatment of water for locomotives on the Missouri Pacific R. R. has materially reduced scale formation and pitting. Foaming is controlled by blowdowns to reduce concentration. Federal rulings require that locomotive boilers be washed every 30 days. They must be kept clean, but the best way to wash a boiler is to do it as seldom as possible. Elimination of throttle box and slotting of dry pipe is suggested to improve conditions against foaming and carry-over. —*R. C. Bardwell.*

Embrittlement in Locomotive Boilers. W. C. SCHROEDER. Proc. Master Boiler Makers' Assn. p. 69 ('39). Embrittlement cracking in riveted seams of locomotive boilers has been encountered and definitely identified on a considerable number of American railroads. To eliminate scale and pitting troubles in locomotive boilers, found necessary to carry definite excess of sodium alkalinity which, when concentrated several hundred-fold by slow leaks in seams, will cause intercrystalline corrosion if right combinations are present and concentrated solution is in contact with highly stressed areas. A simple device, called "Embrittlement Detector," has been developed at the Bureau of Mines. It can be attached to a locomotive and will indicate in 30 days' time if the boiler water has embrittling tendencies so that suitable treatment may be applied. Many railroads now have these embrittlement detectors in service. Records indicate that neither sodium sulfate nor a combination of sodium sulfate and chloride afford protection against intercrystalline cracking in locomotive boilers. Among organic materials, the use of lignin compounds such as waste sulfite liquor and tannins such as quebracho have indicated that very satisfactory protection is possible. Fairly rapid colorimetric tests have been developed for control of this treatment. Practical tests on a large scale are now being made with these materials on many railroads and results to be expected will soon be a matter of record.—*R. C. Bardwell.*

What Water Treatment Has Done for the Illinois Central. ANON. Railway Age **107**: 27: 1002 (Dec. 30, '39). On the western lines of the Illinois Central R. R., through northern Illinois and Iowa, water supply available for locomotive use contains an average of 15 g.p.g. scaling matter. Use of this raw water caused serious damage to boilers, demoralizing train movements. Average

life of flues and fire box side sheets was about 6 mo. Engine failures from leaky boilers averaged one for every 5,000 locomotive miles. 10 lime-soda softening plants installed from '03 to '07 at worst supplies treated 45% of water used and reduced engine failures 96%. Between '18 and '25 facilities were installed to treat all water used west of Freeport, Ill., and by '32 partial treatment was provided between Freeport and Chicago so that since '32 only softened water is delivered to locomotives running west of Chicago. Treatment is controlled and supervised by a chemist and two inspectors with laboratory at Dubuque, Iowa. Blow-down control permits running engine full Federal allowable limit of 30 days between washouts. Flues now run the full Federal limit of 4 years between renewals. Condition of fire boxes has improved to such extent that useful life is indefinite. Engine miles per failure have increased from 5,000 to 10,000,000. A very material decrease has been made in the force handling boiler repairs. Modern locomotives could not be operated on this territory with present requirements for high speed and long engine runs if it became necessary to revert to use of untreated water.—*R. C. Bardwell.*

pH Guides, Selections of Feed-Pump Materials. J. B. GODSHALL. Power **83:** 8: 64 (Aug. '39). 3 factors important in selection of materials for boiler-feed pumps—temp., pressure, and water treatment. A water of pH of 7.0 at 77°F. will have a pH of 5.6 at 482°F. Bronze, and high-chrominum or nickel steels are necessary for internal wearing parts of high-temp., high-pressure boiler-feed pumps where cast iron would ordinarily serve.—*T. E. Larson.*

51 Automatic Pumping Plants Earn 72% Return. ANON. Railway Eng. and Maint. **35:** 12: 754 (Dec. '39). Since '34, the Southern Ry. has conducted an active program for reducing cost of locomotive boiler water. Resulted in installation of 51 automatic stations at a cost of $91,933 and an aggregate annual saving of $66,489 or a return of 72% on investment. Details were adapted to individual locations but most of new pumping units were the close-coupled type motor driven centrifugal pump with flange connections. Automatic control is achieved by magnetic switches in the pump house, actuated by floats in storage tank. Inspection and repairs are handled by signal and water supply maintainers.—*R. C. Bardwell.*

Pumping Equipment to Meet Today's Requirements. M. P. WALDEN ET AL. Railway Eng. and Maint. **35:** 11: 690 (Nov. '39). Speeding up of train schedules and replacement of small capacity (5,000 to 7,500 gal.) locomotive tenders with tenders having capacities exceeding 20,000 gal. has made a material change in water station requirements on railroads. Total amount of water used has not varied appreciably but many minor stations have been abandoned with resulting increase in consumption at others. Steam plants and reciprocating pumps are being replaced with centrifugal pumps driven by either semi-diesel engines or by automatic electric operation. Interstate Commerce Commission records show annual expenditures in excess of $25,000,000 for operation and maintenance of water stations on Class I railroads, indicating that efficient pumping equipment is necessary for economical results.—*R. C. Bardwell.*

SOFTENING AND IRON REMOVAL

The Zerhyd Water Softening Process. ANON. Engineering (Br.) **148:** 105 (Jul. 28, '39). An exhibit at the Paris fair demonstrated the feasibility of softening water by a process analogous to softening by zeolites but using substances which may remove all soluble salts. Chemicals used are called "Allassions." In the process mobile ions are exchanged, as in the zeolite process, but the ions can be replaced by H and OH ions so that the final result is to take out all ions which constituted initial mineral content of the water. In the Zerhyd process, treatment takes place in two stages: water is first passed through Allassion C, where cations are replaced by the ion H; then through Allassion A, where anions are replaced by the ion OH. Allassion C is an insoluble product which, like normal zeolites, contains a percentage of mobile cations. The material gives up cations of H to the water replacing any cations of Ca which were in it originally. A water containing bicarbonates, sulfides, and chlorides of calcium yields only acids, of which carbonic acid can be easily eliminated by simple degassing. When Allassion C is saturated with lime it can be regenerated by an acid, such as dilute sulfuric. Other cations, magnesium, sodium, and iron, follow the same reaction. Allassion A may be regenerated by passing an alkali solution through it. When the water contains silica, preliminary treatment is necessary, since this material, having no pronounced qualities either acid or basic, is not retained by Allassions. The purification plant consists of a series of closed, vertical cylinders, made of acid-resisting metal, containing the Allassions, together with tanks for the regenerating acid and alkali, circulating pumps, etc.—*H. E. Babbitt.*

Progress in Softening of Public Water Supplies. F. K. SINCLAIR. Wtr. & Wtr. Eng. (Br.) **40:** 101 ('38). An account of development of methods of water softening and their adoption for treatment of public water supplies in Great Britain. While it is probable that hard water does not affect health adversely, it leads to scale formation in heating systems and precipitates insoluble curds with soap. In 1841, T. Clark patented a process for softening water by adding milk of lime. Earliest water softening plant for a public supply was installed at Plumstead, Kent, but was abandoned in 1867 because precipitated chalk choked the apparatus. Up to '13 there were only 15 water softening plants in Great Britain. In that year the West Cheshire Water Co. installed the first base-exchange plant at their Hooton works and since then the no. of plants of this type has greatly increased; 19 were constructed in '32–'37. Of the 16 lime softening plants with capacities exceeding 1 m.g.d. now in use, 9 use Clark's original method; recarbonation is employed in 2 cases. Soda is used more generally in industrial plants than in public supply works. There have been several modifications of the lime softening process, including use of steam to agitate the lime and raw water, an automatic siphoning device for adding lime, and mechanical devices for regulating flow of lime water in proportion to amount of water to be treated. The Southend Water Works Co. installed a plant at Langford, Essex, in '27, to treat water by excess lime and recarbonation; the excess lime sterilizes the water. The lime process has lower operating costs than the base-exchange process but difficulties arise in

the disposal of calcium carbonate sludge and in "after-precipitation" of chalk in the distribution system. Latter can be prevented by re-carbonation but skilled supervision is required. The mechanism of the base-exchange process is described. Synthetic zeolites require less space, less wash-water and less salt for regeneration than natural greensands but may be disintegrated by water containing over 15 p.p.m. CO_2. Downward-flow installations are most satisfactory with regeneration by upward flow. It is usual to mix a proportion of raw water with softened water. Recent research work has led to discovery of artificial base-exchange materials prepared from coal, formaldehyde and quebracho tannin. They are regenerated by dilute acids.—*W. P. R.*

Filtering Material for Hot Lime Soda Softeners. J. D. YODER. Power Plant Eng. **42:** 134 (Feb. '38). Tests are described demonstrating desirability of lighter density filtering material, such as anthracite, for hot process softeners. Calcite is reported as good material for the coarse supporting layers.—*T. E. Larson.*

Reaction of Carbonic Acid with the Zeolite in a Water Softener. R. E. KING AND O. M. SMITH. Ind. Eng. Chem. **31:** 727 (Jun. '39). Changes in alkalinity, pH value, and content of CO_2 on filtration of well water through zeolite at 2 power plants in Texas are described and data are given in graphs. At one plant raw water contained 15 p.p.m. CO_2 and at other 7 p.p.m. At former influent water had a total alkalinity of 190 p.p.m. Immediately after regeneration of zeolite effluent contained about 230 p.p.m. alkalinity due to formation of bicarbonate ions in zeolite. The pH value and alkalinity of the effluent decreased as filtration was continued until about 35 p.p.m. CO_2 and only 170 p.p.m. alkalinity were present. Effluent at second plant finally contained over 20 p.p.m. CO_2, and about 160 p.p.m. total alkalinity. Carbonate ions, which were present in effluent immediately after regeneration to extent of over 10 p.p.m., gradually disappeared. Authors suggest that H-zeolite formed by action of carbonic acid on zeolite begins to react with calcium and magnesium salts when concentration of Na-zeolite has been reduced to a limiting value; H ions are produced, and alkalinity of effluent is lowered. After passing carbonated distilled water through zeolitic greensand until no more exchange took place, passage of tap water, with an initial pH value of 7.5, through the zeolite gave an effluent which had a pH value of 4.4 after CO_2 had been removed by heating and aeration. H ions responsible for acidity of effluent must have been derived from carbonic acid in water which had been used to exhaust the zeolite.—*W. P. R.*

Severn Water Supplies and Brine Discharge. ANON. Surveyor (Br.) **95:** 432 (Mar. 24, '39). In considering a bill calling for abandonment of the Droitwich Canal because of possible danger to the water supply of Worcester, it was stated that the authority should not be allowed to discharge into the Salwarpe or Severn NaCl brine in excess of 5,000 lb. of NaCl an hour when the flow of the Severn is less than 500 c.f.s.—*H. E. Babbitt.*

Aeration and Iron Removal for Small Water Supply. ANON. Am. City. **54:** 11:37 (Nov. '39). One of several wells supplies the water needs of Blue

Earth, Minn. Unfortunately, the water contains considerable hydrogen sulfide, iron as iron carbonate, and 62 p.p.m. of CO_2. Before treatment, water drawn from faucets would contain as much as 4 p.p.m. of iron. The well pump now delivers water to the top of a series of trays above a 4-section filter. By a system of pans, the water is well broken up, falling 8′ in the aeration process. This removes the hydrogen sulfide and reduces the CO_2 to below 3 p.p.m. In the summer, a fan is used to force air into the fine streams of water flowing over the aerator trays. The filters are welded iron tanks each 6′ x 20′ containing 12″ of gravel over an underdrain system and 24″ of sand on that. Under the filters, there is a small filtered water storage tank to which the high lift pump suction is attached. Filter washing is done by a backflow from the mains. Installation has given relief to the town from an unbearable taste and red-water situation.—*Arthur P. Miller.*

A New Water-Softening Plant for Shelby, Ohio. ROLLIN F. MACDOWELL. Am. City. **54:** 9: 41 (Sep. '39). Water available to Shelby, Ohio (population 6,800) comes from 2 dug wells 20′ in diam. and 45′ deep. It is very hard and high in iron. The old iron removal plant proving insufficient was abandoned and a new plant consisting of: an aerator; a reaction-settling tank (Spaulding Precipitator); a recarbonation basin; a sludge concentration tank; gravity mechanical filters; a clear water suction basin; sludge lagoons; and a single story building with a 12′ basement was constructed. Aeration is accomplished by passing water through trays of coke. From this treatment device water flows to precipitator into inner compartment of which water and chemicals are fed. Excess sludge from device is drawn to concentration tank and from there flows to lagoons. Although recarbonation tank has been provided, it has not been found necessary yet. Mechanical filters—3 in number—are of usual design. Filtered effluent passes to small suction basin which is connected with clear well in old iron removal plant, holding 120,000 gal., below elevation of filter bottoms. 3 dry feeders for soda ash, lime and alum are provided. New elevated tank was built at same time as plant and utilizes new scheme of preventing formation of rust on inner surfaces (with resultant corrosion) by electrically setting up formation of gaseous hydrogen on wet surface of the tank.—*Arthur P. Miller.*

Water Softening at Hollywood, Florida. WILLIAM SYDOW. Am. City. **54:** 8: 42 (Aug. '39). The Hollywood zeolite softeners were originally installed to use common salt for regeneration. In '38, rapid increase in demand for water required a number of enlargements and extensions. After installing some new and larger mains, a 6″ line between the pumping station and the ocean became available for bringing ocean water to the softeners. Hence, softening equipment was increased in capacity and converted so that sea water could be used. This has effected an annual saving of nearly $7,000.—*Arthur P. Miller.*

America's Largest Zeolite Plant. SCOTLAND G. HIGHLAND. Can. Engr. **76:** 23: 6 (Jun. 6, '39). Water supply of Clarksburg, W. Va., is derived from West Fork of Monongahela R., quality of which is markedly influenced by extensive coal mining activities. Original plant placed in operation in 1889,

rapid sand filter plant completed in '11 and its capacity doubled in '19. Recently, 3 new filters and 4 gravity-type downward flow zeolite softening units were added, housed in abandoned steam pumping-station bldg. Filters equipped for air and water wash, which has given satisfactory results in old installation. Hardness of untreated water varies from 80 to 392 p.p.m., and consists principally of calcium sulfate. Records indicate that softening will be required at least 6 mo. of the yr. Experience will dictate if softening below 80 p.p.m. will be practiced. Softeners contain 66″ of natural greensand. Filtration prior to softening advisable most of time, but provision made for passing filter influent direct to softeners during low turbidity periods. Total cost of 4-m.g.d. softening plant and 3-m.g.d. addition to filter plant was $93,889.—*R. E. Thompson.*

Iron Removal Through Addition of Iron. E. NAUMANN. Gas-u. Wasser. **82:** 151 (Mar. 4, '39). An acid water of about 6.0 pH, having a carbonate hardness of about 100 p.p.m., a non-carbonate hardness of nearly 400 p.p.m., containing iron from 19 up to 40 p.p.m. and manganese from .5 to 1.3 p.p.m. was only partially treated by aeration, passage through marble, short sedimentation and pressure filters. Iron content of the water was reduced to about 5 p.p.m. and manganese content to 0.5 p.p.m., but the water was still corrosively acid and very hard. High organic content, as shown by oxygen consumed from 12 to 28 p.p.m., indicated that organic protective colloids might be the reason for the difficulty in removing iron. Use of ferrous sulfate as a coagulant prior to aeration improved oxidation of all iron in the water. Addition of lime at entrance to the enlarged sedimentation chamber neutralized acidity. The water was free of iron after filtration. Manganese content of the effluent dropped to 0.2 p.p.m. in 3 mo. and in a yr. to a trace. The process uses about 8.5 p.p.m. of ferrous sulfate and this amount is practically independent of the greatly varying iron content of the raw water. Amount of lime used depends mainly on content of free CO_2 in the raw water, but is on the av. 70 p.p.m. Softening is not attempted.—*Max Suter.*

Removal of Iron by Lignin in Water Treatment. G. H. NELSON, M. LEVINE AND D. F. J. LYNCH. Paper Tr. J. 108 ('39) TAPPI Sect. 117. A brief review of available methods for removing iron from water, and a description of an investigation to determine relative efficiency of lignin and a commercial inorganic iron-removing compound in different types of water and on repeated re-use. 29 references to the literature. 500 c.c. samples of raw and treated water or distilled water containing iron salts were shaken with the lignin or the commercial product; results are expressed as p.p.m. of iron remaining in the filtered samples after treatment. Amount of iron removed by the inorganic product was proportional to the concentration of the inorganic product; when 64 p.p.m. lignin was used further increase did not greatly increase the amount of iron removed. Lignin was equally efficient in removing ferric and ferrous iron from distilled or tap water. The initial and final concentrations of iron were 0.09–14.02 p.p.m. and 0.05–0.45 p.p.m. respectively when 64 p.p.m. of lignin were used. For the inorganic compound residual concentration of iron varied from 0.09 p.p.m. (in water containing initially 0.09 p.p.m. iron)

to 6.47 p.p.m. (in water containing originally 14.02 p.p.m.) when 64 p.p.m. of the compound were used. The efficiency of the inorganic compound varied widely with the nature of the water and when re-used repeatedly lost its capacity to remove iron after 6 cycles of mixing, filtering, and drying (using 500 p.p.m.), whereas after 10 cycles, 250 p.p.m. lignin removed over 99% of an initial concentration of 35 p.p.m. iron. A pH value of 6.5–6.6 in water was raised by the commercial compound to 7.4–7.5 and by lignin (250 p.p.m.) to 7.1–7.3. Results indicate that part of the lignin now wasted in the paper pulp and cellulose industry could be utilized for removing iron from municipal and industrial water supplies.—*W. P. R.*

Investigation of the Course of Iron Removal in a Rapid Sand Filter. ALFRED SCHUMACHER. Gas-u. Wasser. **82:** 733, 748 (Nov. 4 and 11, '39). Tests were made on a filter 65 sq. ft. area with about 5′ 8″ depth of sand averaging 1.4 mm. in size. Ground water contained 2.4 p.p.m. FeO and reached the filter after aeration, settling with 1.0 to 1.3 p.p.m. FeO. Filter was arranged to allow visual examination of water in collecting pipe over its whole depth, sampling of water from 13 taps distributed through the depth of the sand, and measurement of loss of head in the flow through the sand by the same 13 taps. It was found that the filters are very sensitive to changes in load, an increase of 8.4% causes iron floc to appear in effluent. Iron floc was found to be very small (± 0.05 mm.). It could be enlarged to 4 or 5 times this size by using increased electrolytical precipitation and coagulation through contact action with iron. This was found by leaving iron deposit on the coke in the aerator and by washing the filter to remove loose iron but not that sticking to the sand grains. This washing was done with higher velocity but for shorter periods so reducing amount of wash water required. Curves given show iron content of water within filter as function of time after washing. They indicate that iron penetrates more and more into filter. Curves for constant iron content are not straight lines, but flatten out, indicating that there is, for each condition, a certain depth beyond which iron content will not rise above a definite value. Increase in rate of filtration increases this depth, meaning that, for a given water and fixed filter rates, a depth of the filter can be found which allows long filter runs without exceeding certain limits of iron in the effluent. Curves for minimum iron show the time that is required for the filter to reach optimum iron removal. Data on iron removal gained from samples taken at different depths and different filter rates are also worked out in characteristics, as are efficiencies relative to time and depth and accumulation of iron within the sand. These show that the top 4″ of sand lose quickly their ability to adsorb iron and that most iron is adsorbed in the layer between 4″ and 16″. The longer the running time the more importance falls on the deeper layers.—*Max Suter.*

Iron Removal Installations Made by the Société Lyonnaise des Eaux in the North-west Suburbs of Paris. ANON. Tech. Sanit. Munic. (Fr.) **33:** 235 (Dec. '38). Methods of iron removal used are classified as follows: (1) oxidation in open air, a coke-filled trickling filter, and sand filtration—installations at Croissy and Poissy-les-Mignaux; (2) closed pressure filters—installations

at Pecq and Villeneuve-la-Garenne; (3) by catalysis or zeolites and by chemical precipitation. At Croissy the installation is called "du Mexique." Water falls in a fine spray on a bed of coke, and is filtered through sand consisting of 0.60 m. of Loire sand, 0.10 m. of coarse sand, and 0.10 m. of gravel. At Poissy-les-Mignaux the coke is only 0.50 m. thick and is equipped with aerators which furnish air from beneath. The sand filter is divided into two compartments each having 0.60 m. of Loire sand resting on a floor of porous cement. The installation is enclosed to prevent contamination from atmosphere. At Pecq the apparatus consists of upright metal tanks 3.20 m. in diam. and 3.10 m. high with hemispherical bottoms. The tanks have perforated floors supporting 2 m. of volcanic lava. Water enters at bottom and is forced upwards through the lava and drawn off at top, passes to sand filters containing 1.50 m. of Loire sand with a layer of coarse gravel underneath. The Villeneuve-la-Garenne installation is of the same type as that at Pecq. It consists of 12 units. Use of catalysis or the zeolitic method is recommended only for very small plants.—*Willem Rudolfs.*

Improved Manufacture of Amine Resins: the Applications Thereof as Base-Exchange Bodies or the Like. W. W. Groves (I. G. Farbenindustrie) A.-G., B.P.489, 173. Describes preparation of the resins. After treatment with alkali, they may be used for removal of impurities from liquids or gases by adsorption or exchange of anions. Exchange activity of a resin is regenerated by treatment with solution of a base such as caustic soda, ammonia or sodium carbonate. Certain more basic resins bring about the selective precipitation of heavy metal salts with formation of the metallic hydroxide, so that when solutions of such salts are passed through the material both anion and cation are retained. Such resins may be used for purifying waste liquors, e.g., resin prepared from polyethylene-imine and 1:2 dichloroethane will completely remove copper sulfate from a 10% aqueous solution, and the resin may be regenerated by strong ammonia. In another example water containing 60 mg. of chlorine ions and 230 mg. of sulfate ions per liter may be completely freed from these ions by filtration through a resin prepared from 1:3-diaminobenzene, polyethylene-imine and formaldehyde; 100 to 120 liters of the water may be treated with an output of 5 liters of filtrate per hr. per liter of material.—*W. P. R.*

CONCRETE

The Design of Reinforced Concrete Reservoirs and Tanks. I. G. M. Cole. Wtr. and Wtr. Eng. (Br.) **41**: 239 (May '39). The loads on structures include: pressure on side walls, live loads and superloads on the structure, wind loads, and foundation loads caused by the weight of water. Side-wall loads due to water pressures are easily computed but those due to earth pressure or contained material, other than water, are uncertain. In general, the familiar methods of Rankin and Cain are recommended. Live loads and superloads should be converted into equivalent depth of the same material as is retained by the side wall, and pressures then recomputed, as before, with the new depths. Allowance for wind should be about 5 lb. per sq. ft. at ground level, increasing 1 lb. per sq. ft. for each 10′ of height to max. of 15 lb. per sq. ft. at

height of 100′. Circular tanks are designed as thin cylinders, tension in the walls being taken by the steel. Real tensile stress on the concrete should not exceed 200 lb. per sq. in. Connection between wall and base may be "free" or monolithic. In monolithic construction wall is designed partly as a cylinder and partly as a cantilever retaining wall. The restraining moment at the base of the wall is FwH in ft. lb., where F is a coefficient dependent on the ratio H/d and H/D, H being height of the wall in ft., D, diam. of the tank in ft., and d, thickness of the wall at the base, in ft. Max. ring tension in the cylinder in lb. is $T = \frac{wHD\,(1 - K)}{2}$ where K it a coefficient depending on H/d and H/D. Point where max. ring tension occurs is KH ft. from the base. If ground is waterlogged tank must be designed not to float when empty.—*H. E. Babbitt.*

Design of Circular Concrete Tanks. (*Discussion of previous paper,* (see abstract Jour. A. W. W. A. **31:** 1239 (Jul. '39)). Proc. A. S. C. E. **65:** 1115 (Jun. '39). FRANK J. MCCORMICK: Author's analysis is not "strictly rigorous", because an analysis based on assumption of ring stress uniformly distributed over thickness of wall is not strictly rigorous except for very thin walls. It can be shown, however, that for a wall of homogeneous elastic material, the assumption is justified in design of tanks of usual proportions. H. B. MUCKELSTON: Author has adjusted ring-steel areas to computed ring stresses on a basis of 12,000 lb. per sq. in. If tank were built to these areas computed ring stresses could not exist since they were computed on hypothesis that steel area was uniform. In fact, if they did exist, deflection would be uniform from bottom to top, which is contrary to hypothesis. It might be argued that leaving cantilever action out of consideration will result in ring cracks near base of wall, but it is questionable if experience would bear out this contention. BASIL SOUROCHKNIOFF: In author's numerical example only stresses due to hydrostatic pressure and curing are computed. As structural stresses are low, temp. stresses may be expected to be proportionately important. Stress distribution analyzed by the author's method is certainly more exact than that obtained by other approx. methods.—*H. E. Babbitt.*

Design of Circular Concrete Tanks. *Closure of Discussion by* GEORGE S. SALTER. Proc. A. S. C. E. **65:** 1800 (Dec. '39). Discussion has emphasized that basic equation is not new and that considerable part of the work has been previously published, principally in German. Use of prestressed rings at top of wall is a patented feature and offers doubtful saving for conditions that prevailed in the design. Although the effect of Poisson's ratio has been neglected and other assumptions have been made, for all practical purposes the method, though not exact, may be justified. Cannot be used, however, for either internal or external loadings to any partial height of the wall. Applicable to large-diam., shallow tanks under the conditions stated.—*H. E. Babbitt.*

Concrete Corners in Tension. D. B. GUMENSKY. Eng. News-Rec. **123:** 411 (Sep. 28, '39). Square or rectangular shape often has advantages over

conventional circular section for low-head inverted concrete siphons. Such was case on Colorado R. Aqueduct, where sections made up of 3 square barrels were used. Corners of such sections, when subjected to internal hydrostatic pressure, tend to crack and open up on inside. To determine most suitable reinforcement, 3 specimens each of 5 types of reinforcement were prepared and tested in tension. Methods are described and results of tests tabulated. Latter show advantage of complete loop in reinforcing bar in corner and addition of crossbar with enclosing fillet.—*R. E. Thompson.*

High Strength Steel Wire as Concrete Reinforcement. DOMENICO DE SIMONE. Ann. Lavori Pub. (Rome) **78:** 364 (Apr. '39). Reinforced concrete construction in Germany and in Italy is at present seriously affected by scarcity of iron. Economy of material has dictated demand for greater strength in the steel. At the same time remarkable advantages of prestressing steel to maximum limit to which it can be subsequently exposed in practice, and then maintaining it in that condition until after concrete has set, have been recognized. Quite obviously, unless bond between steel and concrete is sufficiently great to prevent slippage, advantages will be lost. Hoyer, of Berlin, was first to see that under this system (for several reasons, but chiefly because of low value of the ratio of cross-sectional area to circumference, making slippage impossible) steel wire is most advantageous form of reinforcement. Great success rewarded his perspicacity and, encouraged thereby, he proceeded logically to use of strongest available steel wire, namely piano wire, which is about ten times as strong as ordinary structural steel. Thus he succeeded in reducing by about 90% quantity of iron needed, at same time securing greater strength in his structures. Admirably as this system lends itself to production of pre-cast forms in the factory, practical difficulty of maintaining high stresses in the wires during setting is almost prohibitive. No doubt, with time, this may be overcome. Under high stresses necessary, lateral contraction in the wire is about 1%. When released, free ends of the wire will again expand, even for some distance into the concrete, anchorage thus obtained being an additional guarantee against slippage. Since wires are pre-stressed to extreme maximum which they will have to bear, concrete on tension side of the beam is always in compression, thus avoiding hair cracks on tension side and guaranteeing life of the wires. Incidentally, each wire in structure is thoroughly tested. Illustrations are given of a beam, designed to carry 750 kg./m. and of the same beam with load of 1850 kg./m.—deflection was, of course, very considerable, but none of it was permanent. Joists subjected to vibrational tests of 2,260,000 cycles were uninjured. When tested to destruction, breakage occurs by snapping of the wires; there is no slippage. Illustrations are also given of various beam designs, some of them shelved to support floor slabs which are made on the same principle.—*Frank Hannan.*

Four Thousand Precast Concrete Units Support a Reservoir Roof. BEN E. NUTTER. W. Cons. News. **14:** 413 (Dec. '39). Project of notable importance has been the design and construction of roof of basin, 500′ x 336′ x 29′ deep, of Power Res. at Ventura, Calif., a structure 3.9 acres in extent to cover a treated-water concrete lined res. Considered: (1) cost-in-place concrete,

(2) timber, (3) precast concrete. Comparative costs: (1) 1.5, (2) 0.75, (3) 1.0. 491 — 14′ x 14″ and 93 — 12′ x 12″ columns used; at top of each column 4 bars left protruding to receive welded return bar to make steel continuous—girders rest on top of columns and have stirrups projecting from top surface. Erection routine: (1) concrete footing placed on floor leaving key in top to receive base of column, (2) erection of column, (3) precast girders set between set columns, (4) purlins set on girders, (5) struts placed in position parallel with purlins at column cap, (6) reinforcing steel connections welded, (7) forms set for column caps, girder tops and cast-in-place bridging, (8) forms removed.—*Martin E. Flentje.*

Architectural Concrete. W. D. M. ALLAN. W. W. and Sew. **86**: 427 (Nov. '39). Adaptation of concrete as an architectural medium for water and sewage works is discussed. Discussion covers formwork, ties, concrete control, joints, curing, and stripping. Comments on formwork for decorative treatment are included.—*H. E. Hudson, Jr.*

The Solubility of Cements. F. M. LEA. Wtr. and Wtr. Eng. (Br.) **41**: 508 (Oct. '39). Solubility in cements is an important factor in deterioration of concrete dams exposed to pure and slightly acid waters. Permeability of concrete and extraction of lime from the cement increase rate of decay. With soft waters solution of the lime may become serious. A committee of the Inst. of Civ. Eng. has studied and reported on the problem. Solubility of cements has been studied by three different methods: the results of extraction tests on ground set cements; surface-solution tests on mortars; and percolation tests on mortars which have been compared with those given by percolation tests, under high water pressure, on concrete. Concluded that extraction tests on ground set cements afford a simple measure of the relative susceptibilities to attack of portland, portland blast furnace, and pozzolanic cements. —*H. E. Babbitt.*

Concrete in Sulphate-Bearing Clays and Ground Waters. *Extract From Inf. Bur. of Building Research Sta.* ANON. Wtr. and Wtr. Eng. (Br.) **41**: 518 (Oct. '39). *Part 1.* Various sulfate salts, particularly salts of calcium, magnesium, and sodium, are found in some ground waters. These have a destructive effect on portland cement concrete. In concentrations of 1200 to 2000 p.p.m., in terms of SO_3, it is doubtful if there is any major difference in rate of attack by different sulfate salts. Concrete is not attacked in dry ground containing sulfate salts; water being essential to the action. Attack proceeds inward from the surface at a rate dependent on ease of penetration into the concrete. Resistance to attack increases, within limits, as the proportion of pozzolana is increased. Most resistant type of cement at present available is high alumina cement. From experience such concrete, when well-made may be regarded as immune from attack. It should normally be used in a mix of about 1:2:4 proportions. *Part 2.* **41**: 574 (Dec. '39). Least severe conditions of exposure are offered where there is no flow of water across the concrete face, as in building foundations. One-sided water pressures necessitate increased protective measures. Concentration of sulfates in water

may vary with the season, and in clays may vary widely over a small area of ground. Suggested limits of permissible amounts of sulfates are: (1) Sites with low sulfate content; for ground water less than 300 p.p.m. SO_3; for clay below about 0.2% SO_3. (2) Sites of moderately severe exposure to sulfate attack: for ground water, 300 to 1,000 p.p.m., and for clay 0.2 to 0.5% SO_3. (3) Sites with high risk of sulfate attack; for ground water more than 1,000 p.p.m. and clay, 0.5% of SO_3. Protective measures suggested include: for condition 1 use of 1:2:4 concrete or a richer mixture, cast in place; for condition 2 use of richer concrete, precast cement blocks, and pozzolanic cement (greater precaution is required when magnesium or sodium sulfate is present than when the main sulfate content is gypsum); and for condition 3 use of high alumina cement concrete for most types of work. Under these conditions reliance should not be placed on bituminous paint coatings to portland cement concrete but thick asphaltic coatings applied hot can be regarded as satisfactory. Visual examination of sides of an excavation may be sufficient to reveal presence of sulfate salts. When sulfate crystals are not observed presence of sulfates may be indicated by a white scum or efflorescence left on surface of excavated clay. Water samples should be taken from water actually draining from surrounding sub-soil.—*H. E. Babbitt.*

Calcium Chloride Improves Quality of Concrete Pipe. ANON. Eng. Cont. Rec. **53:** 5: 11 (Jan. 31, '40). Jackson Concrete Pipe Co. uses mix rich in cement, with unusually high percentage of aggregate, low water content and containing CaCl to 1.5-2.0% of wt. of cement. Pipe has crushing strength of approx. 4000 lb. per sq. in. Deliquescent salt absorbs and retains moisture, facilitating complete hydration. Evaporation from molded pipe is retarded and too rapid drying prevented. Workability is also improved. Acceleration of set during winter and high early strength enables early yarding of pipe and speeds production. Even distribution of salt is important. Pipe sections are kiln-cured under steam heat at 80°F. for 4–5 days before yarding. When faster curing is required, temp. is increased to 90°F.—*R. E. Thompson.*

NORMAN J. HOWARD, PRESIDENT, 1940–41

From a drawing by his son—Alan Howard